A MATHEMATICAL PROGRAMMING MODEL OF THE U.S. BEEF SECTOR

By

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Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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The main purpose of this study was to build an economic model of the U.S. beef sector for use in policy analysis. The model developed is a price endogenous spatial equilibrium model. It integrates a system of demand equations for beef with an activity analysis model of the U.S. beef production system. The representation of the beef production system partitions the U.S. into five supply regions and four production stages. The representation of demand for beef partitions the U.S. into four demand regions.

The use of this methodology has been limited by restrictions placed on model formulation by integrability conditions. A new approach was used to solve the integrability problem. In this approach a compensated demand

system is used in place of the more generally used uncompensated demand system.

An inverse Almost Ideal Demand System (AIDS) containing eight meat commodities was derived and estimated for each of the four demand regions. The demand systems were estimated by pooling the data on household expenditures on meat obtained from the Consumer Expenditure Survey, 1982-1986.

The model was used to analyze the impact of an increase in poultry consumption, an increase in beef imports and an increase on beef imports on participants in the beef sector. Increased levels of poultry consumption and increased levels of beef exports caused a decline in the quantity of beef produced and a decline in the size of finished cattle. Increased exports of beef caused both the quantity of beef produced and the size of finished cattle to increase.

The impact of these adjustments on participants in the sector depended on the location of the supply region and the stage of production. The quantity of beef produced declined significantly in the Southeast due to an increase in poultry consumption or beef imports. The decline in the size of finished cattle caused the quantity of cattle finished to decline in the Southwest and to increase in the Plains. The increase in cattle size due to an increase in exports of beef caused the quantity of cattle finished in the Southwest to increase and to decline in the Plains.

CHAPTER 1
CHANGES OCCURRING IN THE STRUCTURE OF THE U.S. BEEF INDUSTRY

The beef industry is one of the most important components of the U.S. agricultural sector. In 1985 consumer expenditures on beef totaled $45.6 billion (USDA, 1988) while on farm cash receipts for beef totaled $29.1 billion. This amount represented 20% of total on-farm cash receipts in the entire agricultural sector for that year (USDA, 1988). In addition, the industry is the major consumer of grains, and as a consequence, changes in the beef industry which affect the supply and demand for beef reverberate throughout the agricultural sector.

The beef industry is in a state of flux with major changes occurring in its structure in both supply and demand. On the supply side the geographic location of production operations is moving westward and sizes of operations are increasing. Specialization in production is intensifying as large commercial feedlots and single species meatpacking plants increase in numbers. Vertical integration is also increasing as meatpacking firms continue to integrate the functions carried out by independent wholesalers into their operations. On the demand side, there has been a dramatic shift in the pattern of meat consumption.

Poultry's share of household expenditures on meat has increased, while beef's share of meat expenditures has declined. The effect of this shift in the pattern of meat consumption is reflected in the decline in the level of per capita consumption of beef throughout the eighties.

The changes presently occurring in the structure of the supply side of the beef industry are largely attributed to two events: the advent of irrigation in the high plains states and the introduction of boxed beef in the meatpacking industry in the mid-sixties. The introduction of irrigation in the high plains has been responsible for the geographic shift in the location of feeding and slaughtering operations while boxed beef is responsible for the increasing size of meatpacking plants and increased vertical integration in the processing and distribution of fresh beef.

Historically, cattle feeding has been located in areas of highly concentrated feed grain production known as the cornbelt, but starting in 1960 a gradual shift occurred in its location as cattle feeding moved away from the cornbelt to the western cornbelt and high plains states of Texas, Nebraska, Kansas, Iowa and Colorado. This shift is primarily a result of the greater availability of feed grain supplies in the plains states and economies of scale resulting from large commercial feedlots (McCoy and Sarhan, 1988) made possible by the introduction of irrigation and the low opportunity cost for land compared to crop production on

nonirrigated lands in this region. Both the greater availability of feed grains and economies of scale led to lower average costs of production, giving these states a comparative advantage in cattle feeding over the central cornbelt states.

The movement of the meatpacking industry has followed that observed for feedlots. Most cattle are slaughtered within 100 miles of where they are finished. This is not surprising given the nature of meatpacking which is essentially a process of reducing the size of the primary input. Thus, the closer the meatpacking facility is located to where the live animal is produced, the less weight that needs to be shipped long distances. When live animals were produced by small atomized producers widely dispersed geographically, the high cost of assembly and transporting the animals to slaughter made it economically infeasible to locate meatpacking facilities at any other location than at the terminal points of transportation routes. However, with the development of large scale feedlots assembly costs were greatly reduced. Thus, the meatpacking facilities were located closer to the areas where the large feedlots were located.

The introduction of boxed beef in 1969 is the most significant technological innovation to occur in the meatpacking industry during the past thirty years. Both the increase in size of meatpacking plants and the increase in

level of concentration in the meatpacking industry have been attributed to the introduction of boxed beef and the economies of scale associated with this technology. It has also transformed the distribution sector since it eliminated the need for specialty wholesalers to service large retail outlets such as grocery chains (Duewer, 1984).

Boxed beef is the end product of a process by which the carcass of the slaughtered cow is fabricated (cut) into primals, subprimals or both, vacuum wrapped and shipped to wholesalers or retailers. Primal cuts consist of the major divisions of the carcass such as rounds, loins, and chucks, while subprimals cuts include the smaller cuts obtained from these divisions, such as chuck steak, and chuck roasts.

Since its introduction the amount of beef marketed as boxed beef has increased steadily and by 1983 accounted for nearly 90% of fresh beef marketings (Duewer, 1984). There are large economies of scale associated with boxed beef. Before the introduction of boxed beef the efficient size packing plant had a capacity of 250,000 head while after its introduction the efficient size plant had a capacity of 1,000,000 head (Marion). In addition to economies of size, boxed beef was widely adopted by the meatpacking industry because it permitted less fat and bone to be shipped, allowed the buyer to order specific cuts, reduced shrinkage during shipping, increased the shelf life of the product, and required less space in shipping (Nelson, 1987a).

As important as the changes occurring in the production of beef are, the most important change is occurring on the demand side where a dramatic shift has occurred in the pattern of meat consumption highlighted by poultry's supplanting of beef as the major meat product consumed (Table 1.1). For thirty years prior to 1977, per capita levels of beef consumption had increased steadily at approximately the same rate as the rate of growth in personal income, reaching a high of 94.0 lbs. in 1976. In 1977, the level of beef consumption dropped to 91.0 lbs. marking the beginning of a period of sharp decline in per capita levels of beef consumption. The decline continued until 1980 when beef consumption dropped to a level of 76.4 lbs. per person. From 1980-1986 per capita beef consumption leveled off, but began to decline again in 1987 when it dropped to 73.4 lbs. During the 1977-1987 time period the level of beef consumption declined by 18.0 lbs. per person. In contrast, the per capita level of consumption of chicken increased steadily during this same time period and in 1987 surpassed that of beef. In 1975 the level of poultry consumption stood at 48 lbs. per person and climbed to a level of 77 lbs. per person in 1987 (Table 1.1). This represents an increase in the level of poultry consumption of 29 lbs. per person.

In addition to the change which has occurred in the consumption pattern among the major meat species, a change

TABLE 1.1 COMPARISON OF PER CAPITA CONSUMPTION OF BEEF AND POULTRY TO THE RELATIVE PRICE OF POULTRY TO BEEF. 1975-87.

Year	Consumption of Beef	Consumption of Poultry	Relative Price of Poultry in Terms of Beef
	lbs.		$
1975	88.0	48.3	.955
1976	94.2	51.6	.947
1977	91.4	52.9	.958
1978	87.2	55.5	.860
1979	78.0	60.1	.708
1980	76.4	60.3	.706
1981	77.1	62.0	.729
1982	76.8	63.4	.706
1983	78.2	64.7	.725
1984	78.1	66.5	.793
1985	78.8	69.7	.791
1986	78.4	72.0	-
1987	73.4	77.8	-

Source: USDA, 1987.

has also occurred in the pattern of consumption found within the beef category itself. In 1965, steak ranked as the number one beef cut in terms of quantity consumed with roasts ranked second and ground beef third. However, by 1984 the picture had changed dramatically as hamburger was now ranked number one, steak had dropped to number two and roasts came in third.

Among agricultural economists there has been considerable debate over the major factors contributing to the changes occurring in the pattern of meat consumption and to the decline in levels of per capita beef consumption. Some have attributed these changes to a fundamental shift in the structure of the demand for meats, due either to increased health concerns on the part of consumers (Chavas, 1983; Braschler, 1983; and Buse, 1986) or an increased desire for convenience in food preparation (Carnes, 1984; Eales and Unnevehr, 1988; and Duewer, 1984). Others assert that the changes which have occurred in the pattern of meat consumption are easily explained by changes which have taken place in such traditional economic variables as the relative price of beef to poultry, income, and the demographic composition of the U.S. population (Haidecker et al., 1982; Chalfant and Alston, 1988; Hager, 1985; Dahlgran, 1987; Heien and Pompelli, 1988).

With regard to the argument that there has been a shift in consumer preferences due to increased health

concerns and need for greater convenience in food preparation, two explanations are usually given to explain how these concerns cause consumers to eat less beef. The first explanation is that the U.S. population has become increasingly concerned about the fat content of their diets due to reports that over consumption of fat leads to heart disease and other health problems. This has led them to try to reduce the amount of fat consumed, especially animal fats. Beef products contain more fat than poultry products. Consequently consumers desire to consume more poultry and less beef in order to reduce the amount of fat in their diet. The second explanation is that the number of two-income households has increased rapidly during the 1975-1987 time period. As a consequence Americans have less time to spend on meal preparation and desire greater convenience or ease of use in food products. The traditional beef products, roasts in particular, require considerably more preparation time and come in larger portions than poultry products. Thus consumers desire more poultry and less beef.

With regard to the argument that it is changes in economic variables such as prices and income which have caused the decline in beef consumption and not a shift in preferences, its supporters point out that the relative price of beef compared to poultry increased significantly during the period in which the changes in the consumption pattern occurred. During the 1975-1985 time period the

price of poultry relative to the price of beef declined by 17% (see Table 1.1). The primary cause of the decline in the relative price of poultry to beef being increased efficiency in the production of poultry which has not been matched by beef producers. Thus as beef becomes more expensive relative to poultry consumers demand more poultry and less beef.

The debate over the cause of declining beef consumption is not just of esoteric interest to econometricians, but has important implications for the beef industry as well. Already, the beef industry is putting its energy into efforts to increase the demand for beef. These efforts include the generic promotion of beef, development of a new grading system by the USDA, private labeling, and the development of new products such as lean beef. However, if the major cause of the decline in beef consumption is due to the increase in the relative price of beef to poultry then the current efforts by the industry to increase demand will be futile. In this case beef producers should have greater success in regaining market share if they concentrate on reducing the cost of producing beef.

All other things being equal, one of the major impacts of the decline in beef consumption will be a reduction in the overall size of the nation's beef herd. It is also likely that the decline in beef consumption and the consequent reduction in the beef herd will accelerate the

current trends in the beef sector with regard to the shift in location of the beef herd, the increase in the scale of operations and the increase in the level of concentration in meatpacking as higher cost participants are squeezed out.

Thus one question which needs to be answered is to what extent these trends will continue. If so, who will be the winners and the losers?

Other areas of concern raised by the current trends focus on their impact on the efficiency of beef production. For example, will increased concentration in meatpacking allow meatpackers to exercise a degree of monopsony power and reduce returns to cattle producers?

Also, the industry's efforts to increase the demand for beef through the introduction of new products such as lean beef and restructured beef cuts has raised many questions concerning the impact of these new products on the sector. How successful will a new product need to be in order to prevent further reductions in the herd size? How will the type of production systems used to produce the new beef products affect the structure of the sector? Will the new production systems change the location of beef production in the U.S.? If meatpacking firms integrate backwards into the production of beef cattle in order to ensure proper quality of their product, how will this affect cow-calf producers?

Policy makers have expressed a need for an integrated model of the U.S. livestock sector which would enable them to assess the impact of the changes in the structure of the U.S. livestock sector on the different sets of producers in the sector (Nelson et al., 1988). The changes that are occurring in the consumption of beef only serve to highlight the need for the development of a model of the beef sector for policy analysis. The purpose of this dissertation is to develop a model for analyzing the impact of changes in the pattern of consumption of meat on the beef industry.

Objectives

The main objective of this research is to develop an integrated model of the U.S livestock sector to be used for policy analysis. The primary use of the model in this study will be to determine the long run impact of the decline in the consumption of beef on the size and location of the beef herd. To this end the following subobjectives are outlined:

1. Determine the technological coefficients on production activities occurring in the beef industry.
2. Estimate a system of regional inverse demand equations for meats to determine the interdependencies among the various meat products.
3. Develop a price endogenous spatial equilibrium programming model of the livestock sector which incorporates a detailed representation of production activities occurring on the supply side and a

set of inverse demand equations for meats to represent the demand side.

4. Use GAMS (General Algebraic Modeling System) as a matrix generator and report writer in order to facilitate the flexibility of the model and to promote its continued usage in the future.

Overview of Study

In the second chapter a discussion of the issues surrounding the use of mathematical programming to conduct economic analysis at the sectoral level is presented. A detailed discussion of the problems associated with incorporating a system of demand equations into a mathematical programming model and the representation of supply curves with an activity analysis model is provided. In Chapter 3 the mathematical formulation of the mathematical programming model of the U.S. beef sector is developed. Chapter 4 contains the specification and estimation of a system of demand equations for fresh meats. Chapter 5 contains the empirical model used for the analysis, and in Chapter 6 the model is used to analyze the impact of the decline in beef consumption on the beef sector.

CHAPTER 2
MATHEMATICAL PROGRAMMING AND SECTOR LEVEL ANALYSIS

Mathematical programming models have been used extensively by agricultural economists to model the livestock industry (Nelson, 1987b). Samuelson (1952) was the first to demonstrate that the spatial equilibrium problem could be cast as a constrained maximization problem. Since then many extensions of the model have been formulated. Takayama and Judge (1971) demonstrated how a spatial equilibrium problem, which incorporates linear supply and demand equations, could be solved as a quadratic programming problem. The application of this formulation, however, has been limited by computational difficulties caused when nonlinear demand and supply equations are introduced. Separable programming techniques developed by Duloy and Norton (1975) broadened the scope of problems which could be solved using this type of analysis by approximating the nonlinear model in such a way as to allow the simplex algorithm to be used to generate solutions. They accomplished this by approximating the nonlinear demand and supply equations with linear line segments. Hazell and Scandizzo (1977) further extended the applicability of the spatial equilibrium analysis by incorporating risk behavior into the formulation. McCarl and

Spreen (1980) discussed price equilibrium models which could be formulated with implicit supply relationships. They have shown that a sectoral level analysis of the type being considered here may be effectively conducted using a price endogenous mathematical programming model. McCarl and Spreen also provide a good summary of the use of these types of models by agricultural economists.

The multicommodity price endogenous programming problem seeks to determine the vectors of prices and quantities which establish a price equilibrium in the markets of several related markets. It takes as data the technological coefficients on production activities, levels of fixed resources, demand relationships of final products, and supply relationships for purchased inputs and generates a solution which gives the equilibrium prices and quantities of final goods, the usage pattern for the factors of production, prices of purchased factors, and imputed prices for owned resources and production activities. The equilibrium is partial because such factors as consumer income and the prices of commodities not endogenous to the system are treated as exogenous variables.

There are several advantages to using a programming model over other techniques given the goals of the study. First, the model's explicit representation of producer behavior allows each production unit to adjust endogenously its supply of products and its use of production inputs.

Thus, the model is able to simulate the response of producers to changes in the economic environment, making it possible to identify not only increases or decreases in supply caused by changes in exogenous variables, but to also identify the pattern of production activities used. Second, the model allows for the introduction of new production activities. Thus, it is possible to simulate the impact of these activities on the profitability of the activity and the effects they will have on the rest of the sector. Third, it does not require knowledge of derived demand and supply curves at each production level of the sector, but only input supply and final product demand curves.

In addition, a price endogenous mathematical programming model theoretically allows the introduction of changes in the demand structure for goods, whether they are due to a shift in consumer preferences or the introduction of new products. Thus, it is possible to determine the impact of the introduction of new technologies, new products, and changes in the demand structure on the industry.

Incorporating Demand Systems into Mathematical Programming Models

The Spatial Equilibrium Model

In order to mathematically formulate the price endogenous programming problem, let

$$P_i = d_i(Q_1, Q_2, \cdots, Q_n | I)$$

denote the inverse demand equation for commodity i, P_i is the demand price of commodity i, Q_i, i=1,$\cdots$,n is the quantity demanded of commodity i, and I is consumer income. Let

$$P^j = s^j (Q^1, Q^2, \cdots, Q^n | Z)$$

be the inverse supply equation for commodity j, P^j is the supply price of commodity j, Q^j, j = 1,$\cdots$,n is the quantity supplied of commodity j and Z is a vector of supply shifters. The constrained optimization problem can be written as

$$\text{Max} \quad NSB = \sum_{i=1}^{n} \int \int \cdots \int d_i(Q_1, Q_2, \cdots, Q_n) \, dQ_1 dQ_2 \cdots dQ_n$$

$$- \sum_{j=1}^{n} \int \int \cdots \int s^j(Q^1, Q^2, \cdots, Q^n) \, dQ^1 dQ^2 \cdots dQ^n \qquad (2.1)$$

$$\text{s.t.} \quad Q_i \leq Q^i \qquad i=1,\cdots,n \qquad (2.2)$$

$$Q_i, \; Q^i \geq 0 \qquad (2.3)$$

The objective function (2.1) maximizes the sum of areas under each demand function less the sum of the areas under each supply function. The inequality (2.2) insures that the quantity demanded is less than or equal to quantity supplied (no excess demand). Expression (2.3) imposes the nonnegativity conditions.

Expression (2.1) is a simplification of the integration that must be performed to properly describe consumer's plus producer's surplus in a multicommodity framework. Following Hazell and Norton (1986, p. 168), a series of line integrals are performed in which the first term is

$$\int_0^{Q_1} D_1(Q_1, Q_2, \cdots, Q_n)\, d\eta_1$$

but all succeeding terms are

$$\int_0^{Q_1} D_1(Q_1, Q_2, \cdots, Q_n \mid Q_1=0, Q_2=2, \cdots, Q_{1-1}=0)\, d\eta_1$$

and similar expressions are formed when integrating the supply functions. For further explanation see Hazell and Norton.

If the demand and supply relationships are linear, e.g.

$$P_i = g_i - \sum_{k=1}^{n} h_{ik} Q_k \quad i=1,\cdots,n$$

and

$$p^j = e^j + \sum_{k=1}^{n} f^{jk} Q^k \quad j=1,\cdots,n$$

then (2.1) - (2.2) can be written as a quadratic programming problem

$$\text{Max} \quad \sum_{i=1}^{n} g_i Q_i - 1/2 \sum_{i=1}^{n} \sum_{k=1}^{n} Q_i Q_k h_{ik} \qquad (2.4)$$

$$- \sum_{j=1}^{n} e^j Q^j - 1/2 \sum_{j=1}^{n} \sum_{k=1}^{n} Q^j Q^k f^{jk}$$

$$\text{s.t.} \quad Q_i \leq Q^i, \quad i=1,\cdots n \qquad (2.5)$$

$$Q_i, Q^i \geq 0. \qquad (2.6)$$

The Integrability Problem

Two important assumptions are made to ensure that the solution of (2.1) - (2.3) is unique. The first assumption is that the income generated from the commodities under study does not affect consumer demand. If the sector under study is small relative to entire economy, this assumption should not prove to be restrictive. Otherwise a general equilibrium framework must be employed. The second assumption is that the demand and supply functions are integrable.

Integrability requires that the Jacobian matrix of both the demand system and the supply system be symmetric. It also requires that the Jacobian matrix of the demand system be negative definite and the Jacobian matrix of the supply system to be positive definite. Symmetry requires that

$$\frac{\partial d_i}{\partial Q_k} = \frac{\partial d_k}{\partial Q_i}$$

and

$$\frac{\partial s_j}{\partial Q^k} = \frac{\partial s_k}{\partial Q^j}.$$

This ensures that the optimal solution to the constrained maximization problem does not depend on the order of integrations. If this requirement is not satisfied there will be as many optimal solutions as there are possible orderings for integration.

Of the two integrability conditions the symmetry requirement for demand systems is believed to be the most difficult to fulfill. The negativity requirement is generally believed to be satisfied if the demand equations are downward sloping and the supply equations are upward sloping.

In the case of supply functions, symmetry is not a stringent requirement following Zusman (1989), ". . . in the

case of supply functions the classical assumptions of the theory of production, in fact, yield the symmetry conditions" (p. 55). However, in the case of consumer demand functions, symmetry is a very stringent requirement. The demand relationship consists of a symmetric substitution effect plus an income effect. The income effect is not generally symmetric. Thus, the assumptions of demand theory do not yield the symmetry conditions.

Approaches to Handling the Integrability Problem

Several approaches have been used to deal with the integrability problem posed by demand systems with non-symmetric cross-price effects. An ad hoc approach is to simplify the demand system so that each demand function includes only own price and own quantity (Hazell and Norton, 1986, p. 168). In this case, all cross-price effects are zero and hence the integrability condition is satisfied.

Another approach is to reformulate the problem by incorporating both price and quantity variables into the primal form of the model (Plessner and Heady). Thus both price and quantity equilibrium conditions are imposed in the primal as opposed to (2.1) - (2.3) in which quantity equilibrium conditions are imposed in the primal and price equilibrium conditions are imposed implicitly through the dual. In the case of linear supply and demand equations, the primal-dual formulation is

$$\text{Max} \sum_{i=1}^{n} (g_i - \sum_{k=1}^{n} h_{ik}Q_k)Q_i - \sum_{j=1}^{n} (e^j + \sum_{k=1}^{n} f^{jk}Q^k)Q^j$$

$$\text{s.t. } Q_i - Q^i \leq 0 \qquad i=1,\cdots,n$$

$$\rho_i(Q_i - Q^i) = 0 \qquad i=1,\cdots n$$

$$(g_i - \sum_{k=1}^{n} h_{ik}Q_k) - \rho_i \leq 0 \qquad i=1,\cdots n$$

$$Q_i(g_i - \sum_{k=1}^{n} h_{ik}Q_k - \rho_i) = 0 \qquad i=1,\cdots n$$

$$-(e^i + \sum_{k=1}^{n} f^{ik}Q^k) + \rho_i \leq 0 \qquad i=1,\cdots,n$$

$$Q^i(e^i + \sum_{k=1}^{n} f^{ik}Q^k + \rho_i) = 0 \qquad i=1,\cdots n$$

$$Q_i, Q^i, \rho_i \geq 0$$

The objective function no longer represents the area between the demand and supply functions but represents net social monetary gain (Takayama and Judge, 1971).

This problem can be solved using linear complementarity programming (LCP) (Takayama and Judge, 1971; Stoecker, 1974). The computer code LINDO (Schrage, 1984) has an option which uses LCP. To be solved by LINDO, the demand system must be linear. For many problems, this

approach is theoretically sound and computationally tractable. For large problems, however, it may pose a problem of size. For example, a problem with 10 commodities, 1000 other primal variables, 10 market clearing inequalities and 500 resource constraints would result in an LCP with 1520 variables and 3,040 constraints.

A third approach to the integrability problem is to transform the demand system so that the Jacobian matrix is symmetric. This is accomplished by averaging the cross-price effects and entering them in the off diagonal positions. The problem with this solution is that the first order conditions are altered so that price no longer needs to equal marginal cost. Consequently, the new optimal solution no longer satisfies the conditions for a competitive equilibrium.

A fourth approach is to use the compensated (Hicksian) demand system rather than the uncompensated (Marshallian) demand system. The Marshallian demand systems do not, in general, satisfy the integrability conditions because the assumptions of demand theory do not imply that the system's Jacobian matrix will be either negative definite or symmetric. However, economic theory does imply that the Jacobian matrix of the compensated demand system will be negative semi-definite and symmetric. Thus it is unnecessary to reformulate the problem.

Following Silberberg (1978, pp. 232-40), let $Q_i = d_i^m(p_1, p_2 1, \cdots, p_n, m)$ $i=1,\cdots,n$ represent the uncompensated demand system and $Q^i = d_i^h(p_1, p_2, \cdots, p_i, u^\circ)$ $i=1,\cdots,n$ represent the corresponding compensated system of demand equations. The Slutsky decomposition of the uncompensated system can be written

$$\frac{\partial d_i^m(p,m)}{\partial p_j} = \frac{\partial d^h(p,u^\circ)}{\partial p_j} - \frac{\partial d_i^m}{\partial m} Q_j^m \qquad (2.7)$$

It shows that the change in the quantity of commodity i demanded due to a change in the price of commodity j can be split into two parts: a substitution effect and an income effect. The substitution matrix is negative definite and symmetric. In equation (2.7) it is represented by the cross-price effect of the Hicksian demand system. Thus, the Jacobian matrix of the compensated demand system is both negative definite and symmetric,

$$\frac{\partial Q^i(p,u^\circ)}{\partial p_j} = \frac{\partial Q^j(p,u^\circ)}{\partial p_i}$$

thereby satisfying the integrability conditions of the price endogenous mathematical programming model.

Is the use of compensated demand functions in price endogenous mathematical programming models appropriate? The answer depends on the difference in the equilibrium position

arrived at when a system of compensated demand equations is used instead of the corresponding system of ordinary demand equations.

As shown in Figure 2.1, equilibrium price and quantity (point E) generated by the simultaneous solution of the uncompensated demand equation (D^m) and the supply equation is identical to the price-quantity pair resulting from the simultaneous solution of the compensated equation (D^h) and the supply equation. But if supply shifts from S to S_1, the equilibrium established by the uncompensated demand equation is at point A, while the equilibrium suggested by the compensated demand equation is point B. The difference in quantity demanded is $q_1^h - q_1^m$ and the difference in price is $p_1^h - p_1^m$.

The difference between quantity demanded and the difference in price will be determined by three factors: (1) the magnitude of the movement away from the original equilibrium, (2) the magnitude of the income elasticity of the commodity for which the price changed, and (3) the share of consumer's income spent on the commodity. Peters and Spreen (1989) examined at the difference in the solutions found by using the compensated and uncompensated demand systems. They used the demand system for meat estimated by Eales and Unnevehr (1988) to simulate the equilibrium established by the uncompensated and compensated demand system. They found that for many agricultural products, such as

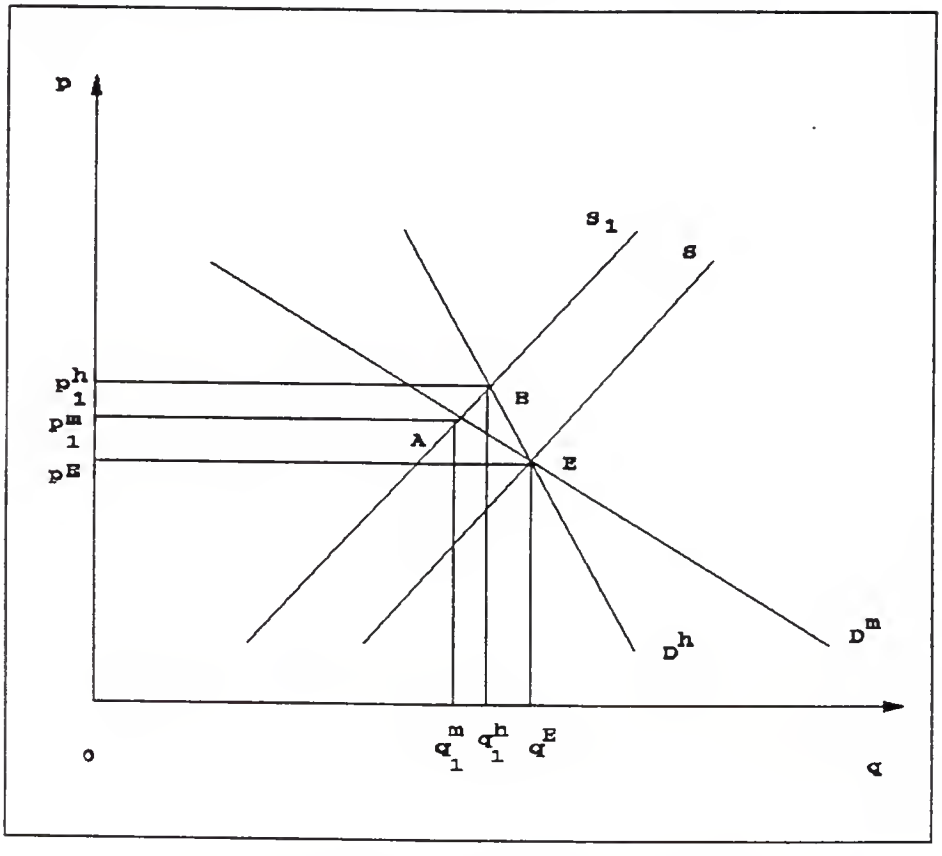


Figure 2.1. Change in equilibrium along compensated and uncompensated demand curves due to an exogenous shift in supply.

beef, there will be little difference between the two solutions.

This fourth approach is the one that will be used to formulate the programming model of the U.S. beef sector. It has been selected because it permits the integrability conditions to be satisfied without reformulating the problem as required in complementary programming. This preserves the economic meaning of the objective function, reduces the size of problem to be solved, and permits nonlinear demand systems to be used with little cost with respect to the accuracy of the solution.

CHAPTER 3
A MODEL OF THE U.S. BEEF SECTOR

The purpose of this chapter is to develop a price endogenous sectoral level programming model of the U.S. beef sector. It is important that the model accurately portray the activities occurring in the sector. In the first section the production activities which are found in the sector are described. This has the additional benefit of providing a foundation for validating the base model. The material contained in this section has been drawn from four major sources: Marion (1986), McCoy and Sarhan (1988), Simpson and Farris (1982), and Nelson (1987a). In the second section the cattle cycle, sector supply response and the usefulness of static versus dynamic models of the sector are discussed. In the final section the mathematical formulation of the model is laid out and described.

Organization of the Beef Sector

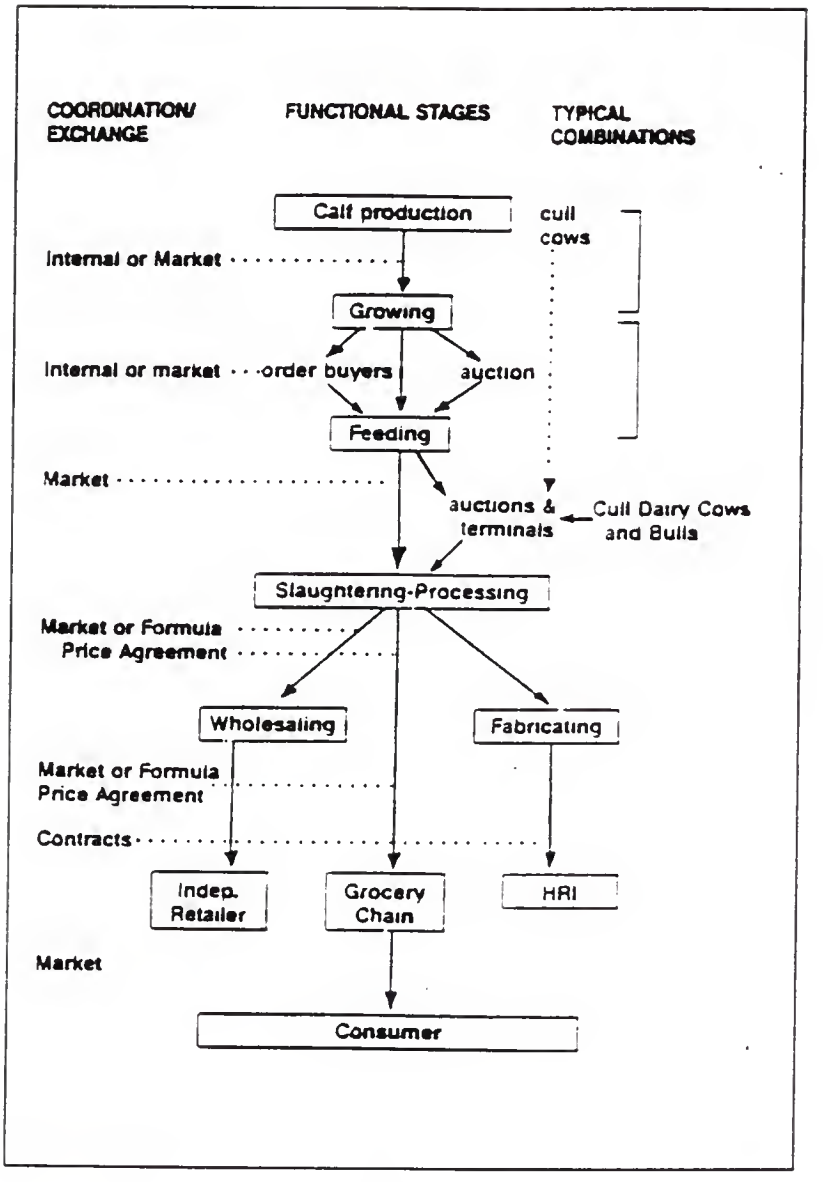
The organization of the beef sector is complex and the task of coordinating production activities in the industry is difficult. The time frame for producing beef is long. It takes about 2 1/2 years from the time of breeding to the slaughter of a mature animal. Also, a relatively large proportion of cattle and calves change ownership as they

move through the stages of production, except at the distribution stage where processors and retailers have taken over wholesale activities. Coordination is made even more complex by the distance between the major areas of beef production and the main demand centers.

Given the complexity of its organization it is convenient to arrange production activities occurring in the sector into a vertical system (Figure 3.1). There are five major stages of production in the vertical system: cow-calf, growing, finishing, slaughtering and processing, and distribution. The initial products (beef calves) enter the system at the cow-calf stage and are passed sequentially through the next four stages of production until they reach their final form (fresh beef products). At this point they are sold to consumers and exit the system.

The Cow-Calf Stage

The primary activities occurring at the cow-calf stage are the maintenance and breeding of the cow herd and the production of stocker or feeder calves. This includes feeding, breeding and culling of the cow herd and the production of calves. The primary inputs required at this stage of production are land for grazing, breeding stock, and harvested roughage. The level of investment for operators is high. Consequently, operations are affected by changes in land values and interest rates.



Source: Marion, 1986.

Figure 3.1. Organization of the beef sector.

Calves are weaned at the age of six months. They are then either retained for replacement of culled breeding stock or to expand the cow-herd, sent to the growing stage, or sent directly to the finishing stage. The decision to carry the weaned calf into the growing stage is determined by the availability of forage. In some operations calves are placed on feed for a short time after they are weaned and then sold as vealers.

The decision to retain the weaned calf for the cow herd is based on the size of herd the cow-calf operator wants to maintain. If the cow-calf operator feels the cow herd needs to be increased then more calves need to be retained than the number required for replacement of culled breeding stock. Likewise, if the operator wants to decrease the size of the cow herd, then less calves will be retained than the amount needed to replace culled breeding stock.

The Growing Stage

In the growing stage weaned calves are placed on forage and roughage for a period of 6 to 12 months for the purpose of increasing the development of the body frame. This stage in the production process is often referred to as the stocker or backgrounding stage. From the growing stage stockered cattle are either sent directly to the slaughter plant for processing as nonfed beef or sent to the finishing stage to be fattened for slaughter. The most common route used is from backgrounding to the finishing stage then to

the processing stage to be slaughtered. While the marketings of nonfed beef are significant the far greater amount of cattle are marketed as fed beef. For example, in 1988, fed beef comprised 78% of the total of beef cattle slaughtered (USDA, 1989). In addition, most of the nonfed beef slaughter comes from beef and dairy culls.

The Finishing Stage

At the finishing stage the cattle are confined in a feedlot and placed on a high concentrate ration. The major production inputs used at this stage are feeder cattle, feed, feeding facilities, feed storage facilities, and feed processing and delivery equipment. Feeder cattle enter the feedlot from either the cow-calf or stocker stages. The animals are kept on the feedlot for varying lengths of time depending on their placement weight and the slaughter cattle to corn price ratio. The lower the ratio the shorter the period of time the cattle are retained on the feed lot. Cattle placed in feedlots immediately after weaning are fattened to a light slaughter weight (900-1100 lbs.). Yearlings are either short-fed to a light weight or long-fed to a heavy slaughter weight (1200-1300 lbs.). Older placement cattle are finished heavy. The usual time period for finishing is six months. From the finishing stage the cattle are sent to the meatpacking plant for slaughter.

The three production stages described above are not totally separate or distinct from each other. A large

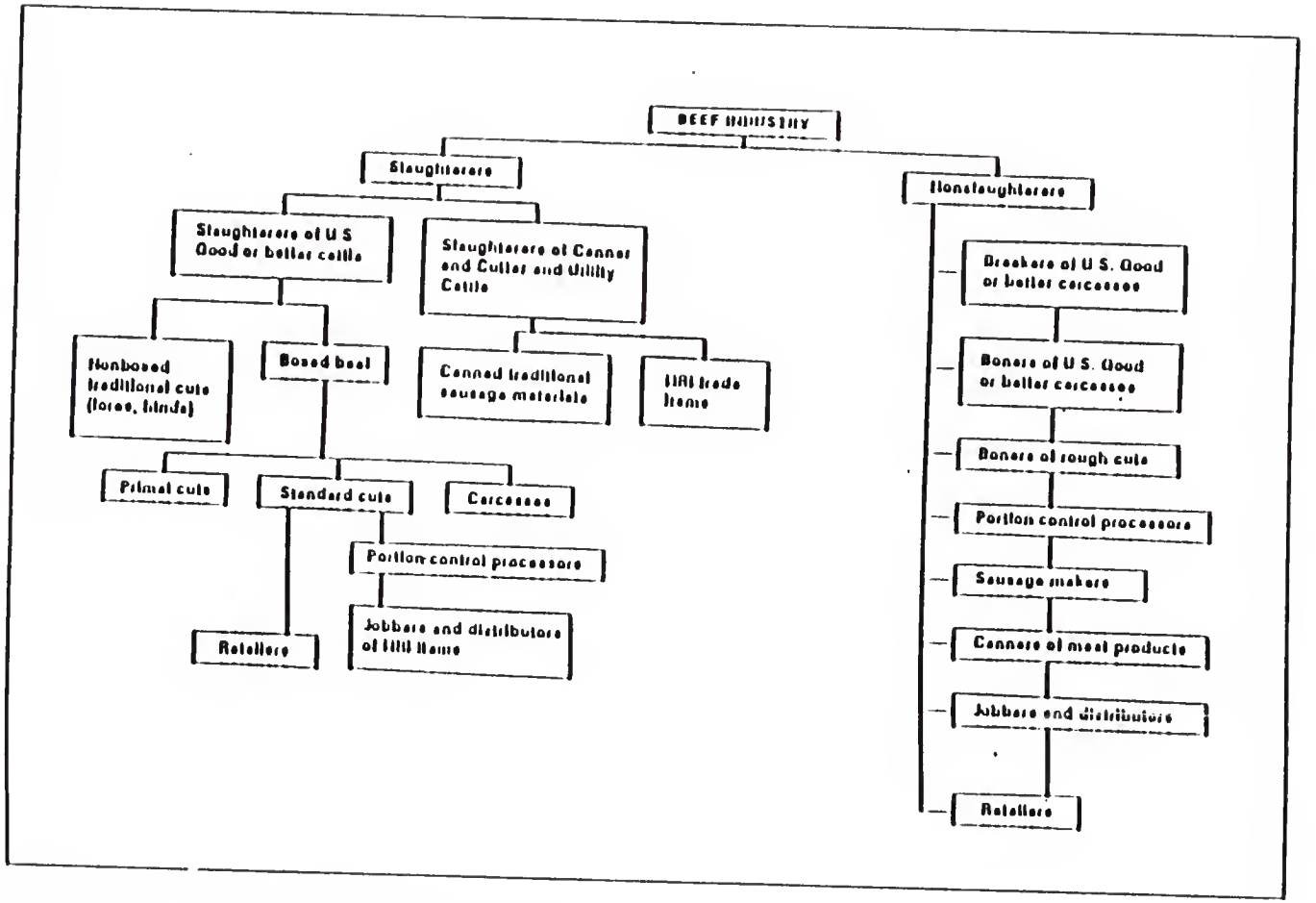
portion of enterprises found at these levels of the vertical system have integrated more than one of the production stages into their operations. However, it is uncommon for all three stages to be completely integrated under the umbrella of a single enterprise. The stocker stage is the least distinct of the production stages as it is often integrated into either the cow-calf or finishing stages.

The Slaughtering and Processing Stage

The slaughtering and processing stage encompasses all activities involved in the slaughter of beef cattle and the cutting of carcasses into smaller units for sale to independent wholesalers or retail outlets. Primary inputs used at this stage are slaughter cattle, facilities, labor, and containers. Live animals can enter the meat-packing plant from the cow-calf stage, the stocker stage, the finishing stages or the dairy herd. They are killed, halved, dressed and their carcasses chilled. The chilled carcasses are then either sold or cut up further into boxed beef. The calves coming from the cow-calf stage or the dairy herd are processed as vealers, while cattle coming from the stocker stage or the culled dairy and beef herd are slaughtered as nonfed beef.

The Distribution Stage

The distribution system for fresh beef is complex and contains many components (Figure 3.2). The wholesaler



Source: McCoy and Sarhan, 1988.

Figure 3.2. Major components of meat processing and distributing.

classification includes both the activities of processors and retail enterprises which perform the wholesale function as well as independent wholesale organizations. At present the marketing of beef products is dominated by processors that sell directly to retail outlets. It is estimated that over 80% of total beef production is marketed as boxed beef (Duewer, 1984).

In the distributing stage fresh beef is moved from the processing stage to the retail outlets. Retail outlets can be broken into two groups: retail supermarkets and the hotel, restaurant, and institutional (HRI) trade. Retail supermarkets are the most significant outlet for fresh beef although the importance of the HRI trade is growing. Large retail supermarkets maintain central warehouse facilities for handling boxed beef purchased from the meat packing plant. Some of the supermarket chains also maintain a central cutting facility where carcasses are fabricated into boxed beef.

Many of the smaller food stores and HRI outlets require the services of independent wholesalers. Brokers do not take ownership of the beef products but execute sales on a commission basis. Jobbers buy and sell to retail customers. Purveyors also sell on their own account, but specialize in providing beef to a special set of clientele, such as expensive hotels.

Regional Structure of the Industry

Cattle raising[1] is widely dispersed throughout the U.S. Some 31 states individually account for at least 1% of total beef cattle production (Table 3.1). However, cattle raising is not evenly distributed geographically. Of the 19 states producing less than 1% of the total amount of beef cattle, 15 are located in the heavily populated Northeast. On the other hand the top 6 producing states account for 41% of production. All are located west of the Mississippi River and east of the Rocky Mountains. In all, 57% of beef cattle production is located between the Mississippi River and the Rocky Mountains.

Most beef cattle operations are small, with an average herd size of 34 head. Seventy percent of calves produced come from cow herds with less than 200 head (Nelson, 1987a).

Boykin et al. (1980) has identified four production systems which characterize the type of enterprises involved in cattle raising: cow-calf-feeder, cow-calf-slaughter, stocker purchase-slaughter sales, and stocker purchase-feeder sales. The cow-calf-feeder system includes both the cow-calf and cow-calf-yearling operations. In the cow-calf operation calves are sold after weaning, whereas in the cow-calf-yearling operation, calves are carried over into the growing stage and then sold to a feedlot for finishing.

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[1]Cattle raising includes both the cow-calf and stocker stages of production.

TABLE 3.1. NUMBER OF CATTLE BY STATE AND STATE'S SHARE OF U.S. TOTAL, 1988.

Region	State	Beef Cows	Milk Cows	Total	Beef's Share of Total	State's Share of U.S. Total	State's Share of Region Total
		000			%	%	
Northwest	CONN	5.0	37.0	42.0	11.9	0.0	1.4
	DEL	2.0	9.0	11.0	18.2	0.0	0.5
	MAINE	9.0	47.0	55.0	14.5	0.0	2.2
	MASS	10.0	33.0	43.0	23.3	0.0	2.7
	NH	5.0	23.0	28.0	17.9	0.0	1.4
	NJ	11.0	31.0	42.0	26.2	0.0	3.0
	NY	112.0	844.0	956.0	11.7	0.3	30.4
	PA	206.0	724.0	930.0	22.2	0.6	55.9
	RI	0.8	2.9	3.7	21.6	0.0	0.2
	VT	9.0	170.0	179.0	5.0	0.0	2.4
	TOTAL	369.0	1,921.0	2,290.0	16.1	1.1	100.0
Southeast	ALA	875.0	40.0	915.0	95.6	2.7	12.6
	FLA	1,086.0	179.0	1,265.0	85.8	3.3	15.6
	GA	703.0	102.0	805.0	87.3	2.1	10.1
	KY	1,017.0	218.0	1,235.0	82.3	3.1	14.6
	MD	53.0	113.0	166.0	31.9	0.2	0.8
	MISS	706.0	68.0	774.0	91.2	2.1	10.1
	NC	320.0	105.0	425.0	75.3	1.0	4.6
	SC	284.0	43.0	1,190.0	82.9	3.0	14.2
	VA	690.0	145.0	835.0	82.6	2.1	9.9
	W VA	248.0	31.0	279.0	88.9	0.8	3.6
	TOTAL	6,968.0	1,248.0	8,216.0	84.8	21.1	100.0

Southwest	ARK	945.0	72.0	1,017.0	92.9	2.9	10.9
	LA	615.0	87.0	702.0	87.6	1.9	7.1
	OKLA	1,842.0	108.0	1,950.0	94.5	5.6	21.3
	TEX	5,260.0	340.0	5,600.0	93.9	16.0	60.7
	TOTAL	8,662.0	607.0	9,269.0	93.5	26.3	100.0
Midwest	ILL	525.0	210.0	735.0	71.4	1.6	5.0
	IND	370.0	190.0	560.0	66.1	1.1	3.5
	IOWA	1,210.0	299.0	1,509.0	80.2	3.7	11.5
	KANS	1,466.0	104.0	1,570.0	93.4	4.4	13.9
	MICH	130.0	358.0	488.0	26.6	0.4	1.2
	MINN	370.0	810.0	1,180.0	31.4	1.1	3.5
	MO	1,866.0	224.0	2,090.0	89.3	5.7	17.7
	N DAK	871.0	99.0	970.0	89.8	2.6	8.3
	NEBR	1,680.0	100.0	1,780.0	94.4	5.1	15.9
	OHIO	412.0	368.0	780.0	52.8	1.3	3.9
	S DAK	1,448.0	147.0	1,595.0	90.8	4.4	13.7
	WIS	200.0	1,790.0	1,990.0	10.1	10.6	1.9
	TOTAL	10,458.0	4,699.0	15,247.0	69.2	32.0	100.0
Plains	ARIZ	260.0	90.0	350.0	74.3	0.8	5.7
	COLO	778.0	72.0	850.0	91.5	2.4	17.1
	IDAHO	510.0	160.0	670.0	76.1	1.5	11.2
	MONT	1,275.0	25.0	1,300.0	98.1	3.9	28.1
	N MEX	527.0	59.0	586.0	89.9	1.6	11.6
	NEV	246.0	19.0	265.0	92.8	0.7	5.4
	UTAH	318.0	78.0	391.0	81.3	1.0	7.0
	WYO	630.0	10.0	640.0	98.4	1.9	13.9
	TOTAL	4,544.0	508.0	5,052.0	89.9	13.8	100.0

TABLE 3.1.--continued

Region	State	Beef Cows	Milk Cows	Total	Percent Beef of Total	State Percent of U.S. Total	State Percent of Region Total
		000			%	%	
West	ALAS	2.5	2.3	4.8	52.1	10.0	0.1
	CALIF	895.5	1,004.7	1,900.2	47.1	2.7	47.7
	HAW	73.0	12.0	85.0	85.9	0.2	3.9
	OREG	547.0	94.0	641.0	85.3	1.7	29.2
	WASH	359.0	211.0	570.0	63.0	1.1	19.1
	TOTAL	1,877.0	1,324.0	3,201.0	58.6	5.7	100.0
U.S.	TOTAL	32,958.0	10,307.0	43,265.0	76.2	100.0	-

Source: USDA, 1989.

In the cow-calf-slaughter system weaned calves are carried over into the stocker stage and sold as slaughter calves or kept in the stocker stage longer and sold as nonfed beef. In some instances operators using this system will place stocker cattle into feedlots and then sell them as fed cattle. In the stocker purchase-slaughter sales system weaned calves are purchased and placed on small grasses, field stocks, and other feed sources through the growing stage, then placed in a feedlot for finishing and then sold for slaughter. Finally, in the stocker-purchase-feeder sales system, operators purchase weaned calves and place them on range or pasture during the growing stage. Feeder cattle are then sold to feedlots for finishing.

The type of beef production system found in a region is determined by availability of forage, feed, and alternatives to cattle production. Of the four systems described the most prevalent is the cow-calf-feeder system. The cow-calf system predominates in the southeast while cow-calf-stocker operations are common in the great plains states. In the midwest the stocker purchase-slaughter sale system predominates.

Given the current conversion rate of feed into gain for beef cattle the finishing of beef cattle occurs primarily in the regions where feed grains are produced (see Table 3.2). Finishing operations are more highly concentrated geographically than cattle production. In 1988, the

TABLE 3.2. NUMBER OF CATTLE FEEDLOTS AND FED CATTLE MARKETED BY SIZE OF FEEDLOT CAPACITY, 13 STATES, 1987.

	Cattle Feedlot Capacity (head)							
	< 1,000		1,000-2,000		2,000-3,999		4,000-7,999	
State	Lots	Marketed (000 hd)	Lots	Marketed (000 hd)	Lots	Marketed (000 hd)	Lots	Marketed (000 hd)
ARIZ	9	17	0	0	-	-	-	-
CALIF	10	3	5	7	7	15	10	51
COLO	140	45	50	90	55	200	30	265
IDAHO	35	10	15	10	15	30	6	50
ILL	8,750	725	40	60	10	40	0	0
IOWA	9,655	1,215	250	321	95	214	-	-
KANS	1,627	70	92	71	57	190	34	267
MINN	5,931	432	53	65	16	43	0	0
NEBR	8,950	1,340	175	340	135	570	77	690
OKLA	206	30	-	-	4	17	3	8
S DAK	4,146	269	24	67	17	77	13	237
TEX	849	90	9	20	12	35	21	170
WASH	62	6	-	-	7	35	-	-
TOTAL	40,353	4,226	723	1,061	409	1,320	211	1,690

Source: USDA, 1989.

TABLE 3.2--Extended

Cattle Feedlot Capacity (head)						Total of all Feedlots	
8,000-15,999		16,000-31,999		> 32,000			
Lots	Marketed (000 hd)	Lots	Marketed (000 hd)	Lots	Marketed (000 hd)	Lots	Marketed (000 hd)
-	-	6	177	5	266	20	4
11	98	11	266	6	365	60	7
16	310	11	425	8	895	310	22
6	100	4	260	-	-	81	4
-	-	0	0	0	0	8,800	8
-	-	0	0	0	0	10,000	17
49	1,014	26	1,065	15	1,353	1,900	40
0	0	0	0	0	0	6,000	5
45	920	13	540	5	500	9,400	49
8	83	4	142	5	410	230	6
-	-	-	-	0	0	4,200	6
36	625	40	1,385	33	2,930	1,000	52
5	33	6	342	-	-	80	4
185	3,285	119	4,347	81	7,042	42,081	229

top 13 states with respect to number of cattle on feed account for 85% of fed beef marketed and the top 6 states account for 67% of fed beef marketed (see Table 3.3).

Finishing operations can be grouped into farmer and commercial classifications. The typical farmer operated feedlot maintains a one time carrying capacity of less than 1,000 head. The feedlot is often just one of several enterprises operated on the farm, and cattle are on feed only part of the year. In contrast, the commercial feedlot has a one-time carrying capacity greater than 1,000 head are operated as single enterprises and feed cattle the year round. Regionally, the majority of the farmer feedlots are found in the midwestern states of Iowa, Illinois, and Nebraska, while the commercial feedlots are found in the southwest and great plains states. While a majority of feedlots are farmer feedlots the majority of fed slaughter cattle come from the commercial feedlots. Feedlots with a capacity of less than 1,000 head accounted for 18% of cattle marketed in 1987, whereas feedlots with capacity of greater than 8,000 head accounted for 64% of cattle marketed in that year (see Table 3.3).

The location of slaughter and processing plants mirrors the location of feedlots (see Table 3.4). Most cattle are slaughtered less than 100 miles from where they were fed.

TABLE 3.3 STATE PERCENTAGE OF TOTAL U.S. FED CATTLE MARKETED BY FEEDLOT SIZE, 13 STATES, 1987.

State	Feedlot capacity							
	1,000	1,000-1,999	2,000-3,999	4,000-7,999	8,000-15,999	16,000-31,000	>32,000	Total
	%							
ARIZ	0.4	0.0	0.0	0.0	0.0	4.1	3.8	2.0
CALIF	0.1	0.7	1.1	3.0	3.0	5.2	5.2	3.3
COLO	1.1	8.5	15.2	15.7	9.4	9;.18	12.7	9.7
IDAHO	0.2	0.9	2.3	3.0	3.0	6.0	0.0	2.0
ILL	17.2	5.7	3.0	0.0	0.0	0.0	0.0	3.6
IOWA	28.8	30.3	16.2	0.0	0.0	0.0	0.0	7.6
KANS	1.7	6.7	14.4	15.8	30.9	24.5	19.2	17.5
MINN	10.2	6.1	3.3	0.0	0.0	0.0	0.0	2.4
NEBR	31.7	32.0	43.2	40.8	28.0	12.4	7.1	21.3
OKLA	0.7	0.0	1.3	0.5	2.5	3.3	5.8	3.0
S DAK	6.4	6.3	5.8	14.0	0.0	0.0	0.0	2.8
TEX	2.1	1.9	2.7	10.1	19.0	31.9	41.6	22.9
WASH	0.1	0.0	2.7	0.0	1.0	7.9	0.0	1.8
13 STATES	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: USDA, 1989.

TABLE 3.4. U.S. FEDERALLY INSPECTED CATTLE SLAUGHTER BY REGION, 1988.

Region	Types of cattle					Total	
	Steers	Heifers	Dairy cows	Other cows	Bulls & Stags	Number	Percent
	000						
Northeast	508.6	119.1	599.6	115.0	53.0	1,395.3	4.1
Southeast	134.9	210.2	201.4	540.6	85.9	1,173.0	3.4
Midwest	9,572.5	6,189.8	1,347.0	1,184.3	236.8	18,530.4	54.4
Southwest	3,261.9	1,798.7	132.5	811.2	121.4	6,125.7	18.0
Plains	1,490.5	1,513.5	122.7	238.1	55.2	3,420.0	10.0
West	1,865.0	607.4	475.6	383.2	72.6	3,403.8	10.0

Source: USDA, 1989.

Due to the substantial economies of scale associated with boxed beef two types of enterprises have evolved. The efficient size of slaughter-processing plant which produces boxed beef as an output is believed to be between 500,000 to 1 million head annual capacity (Marion, 1986). One type is the large slaughter-processor with plant capacity often exceeding 500,000 head who specialize in fed beef and sell their output as boxed beef. The other type of enterprise operates a smaller capacity plant and caters to smaller, specialized customers. The number of firms at this stage is small. Concentration measures indicate that the top four firms involved in slaughter and processing of beef account for 82% of fed beef slaughtered (Marion, 1986).

Dairy Herd

The culls from the dairy herd are a significant source of beef, typically accounting for 20% of total cattle slaughter. As a consequence, the amount of dairy culls slaughtered do have an important effect on price received by producers in the beef sector. However, the quantity of culls coming from the dairy sector is not determined by conditions found in the beef system, but by conditions prevailing in the dairy sector. Thus the supply of dairy culls is exogenous to the beef system. The slaughter of cull cows is more dispersed than the slaughter of fed beef reflecting the distribution of cow-calf operations and the dairy herd.

Foreign Trade

Like the dairy herd, foreign trade is significant but does not play a major role in the decisions made by beef producers. Thus, level of imports and exports can be treated as exogenous to the sector. It must noted here, the role of foreign trade is increasing and that domestic beef producers hope that increase in beef exports to foreign markets will offset the decline in beef consumption in the U.S.

Supply Response

Given the long lag in time from when the decision to produce a calf is made to the time that the live animal is slaughtered, the decisions made at the cow-calf stage ultimately determine the supply of beef at any point in time. Thus, the sectors supply response of the sector is determined by the ability of cow-calf operators to increase or decrease the number of feeder calves produced.

Cow-calf operators cannot increase production rapidly in response to favorable market conditions due to two related factors. First is the length of time it takes to produce new breeding stock. It takes two years to produce a heifer for breeding purposes. Second, there are no alternative uses for breeding stock other than for the production of calves. As a consequence, breeding stock in excess of the amount needed to meet calf production needs are not kept but sold for slaughter.

The slowness of the supply response is believed to be the principal cause of the cattle cycle. The cattle cycle has been observed to last 10 years starting with a 3 to 4 year period of contraction in the number of beef cattle produced followed by a 6 to 7 year period of expansion.

The discussion on the sector's supply response raises the issue of time and the appropriateness of casting the model of the beef sector in a static or dynamic framework. A resolution to the time problem depends on the type of information one is interested in gaining. If one is interested in forecasting the prices received by producers or cattle numbers at any particular point in time then a dynamic framework is appropriate. However, if one is interested in long-run trends then the dynamic framework is a hindrance. The seasonal fluctuations and production cycles which are incorporated in a dynamic model only serve to hide the trend. In this case a static framework is appropriate.

The Model

The description of the organization of the beef sector serves as a conceptual framework with which to mathematically formulate the programming model. The system for beef production is represented by a linear activity analysis model. Regional differences in the production of beef are accounted for by building an activity analysis model for each supply region. The demand for beef is represented by a system of demand equations for meat at the retail level.

Transportation activities permit the transportation of live animals between supply regions and boxed beef from supply regions to demand regions. The size of the breeding herd, the level of beef imports and the level of dairy culls slaughtered are exogenously determined.

Conceptually the model is not complicated. It is a spatial equilibrium model where the supply functions are being implicitly represented have been replaced by a linear activity analysis model of beef production. The mathematical representation of the model is complicated by the number of dimensions to each variable. However, the production activities in one region are simply replicated for the other supply regions. The supply models differ by the values of their parameters. Variables and their dimensions are defined in Tables 3.5 and 3.6.

The beef production system as represented by the following model draws heavily from earlier versions of the model developed by Nelson et al. (1982), Kennedy (1982), and Disney (1989). The structure of the model and variable definitions are as defined in Nelson et al. and Kennedy. The parameter values were updated by Disney.

TABLE 3.5. VARIABLE DIMENSION DEFINITIONS

Subject	Description
Regions	
Supply regions are identified by:	
(i,i')=1,2,3,4,5	i=1 Southeast i=2 Midwest i=3 Southwest i=4 Plains i=5 West
Demand regions are identified by:	
j=1,2,3,4	j=1= Northeast j=2= South j=3= Midwest j=4= West
Production Stages	
Production stages are identified by:	
s=1,2,3,4,5	s=1 = cow-calf stage s=2 = stocker or growing stage s=3 = finishing stage s=4 = slaughtering stage s=5 = hamburger processing stage
The Cow-calf Stage	
Production processes used are identified by:	
k1=1,2	k1=1 = producing a weaned calf k1=2 = culling breeding stock

TABLE 3.5.--Continued

Subject	Description
Types of cattle produced are identified by: u1=1,2	u1=1 = weaned calf u1=2 = cull
The Stocker Stage Type of animal used in production activities are identified by: v2=1	v2 = weaned calf
Production processes used are identified by: k2=1,2	k2=1 = producing a yearling k2=2 = producing a 1 1/2 year old
Types of cattle produced are identified by: u2=1,2	u2=1 = yearling u2=2 = 1 1/2 year old
The Finishing Stage Type of animal used in production activities are identified by: v3=1,2,3	v3=1 = weaned calf v3=2 = yearling v3=3 = 1 1/2 year old
Production processes used are identified by: k3=1,2,3,4,5,6	k3=1 = producing 900 lb. animal from a weaned calf

TABLE 3.5.--Continued

Subject	Description
	k3=2 = producing 1100 lb. animal from a weaned calf k3=3 = producing 1200 lb. animal from yearling k3=4 = producing 1300 lb. animal from 1 1/2 year old k3=5 = producing 900 lb. animal from yearling k3=6 = producing 1100 lb. from 1 1/2 year old
Types of cattle produced are identified by: u3=1,2,3,4	u3=1 = 900 lb. animal u3=2 = 1100 lb. animal u3=3 = 1200 lb. animal u3=4 = 1300 lb. animal
The Slaughtering Stage Types of meatpacking plants used are identified by: l=1,2,3,4,5	l=1 = plant 1 l=2 = plant 2 l=3 = plant 3 l=4 = plant 4 l=5 = plant 5
Type of animal used in production activities are identified by: v4=1,2,3,4,5,6,7	v4=1 = 900 lb. fed animal v4=2 = 1100 lb. fed animal

TABLE 3.5.--Continued

Subject	Description
	v4=3 = 1200 lb. fed animal v4=4 = 1300 lb. fed animal v4=5 = yearling v4=6 = 1 1/2 year old v4=7 = cull
Production activities used are identified by: k4=1,2,3,4,5,6,7	k4=1 = fabricate 900 lb. fed animal k4=2 = fabricate 1100 lb. fed animal k4=3 = fabricate 1200 lb. fed animal k4=4 = fabricate 1300 lb. fed animal k4=5 = fabricate yearling k4=6 = fabricate 1 1/2 year old k4=7 = fabricate cull
Product forms produced are identified by: u4=1,2,3,4,5	u4=1 = roast u4=2 = steak u4=3 = lean trim u4=4 = medium trim u4=5 = fat and bone
The Hamburger Processing Stage Product forms used are identified by: v5=1,2,3,4	v5=1 = roast v5=2 = steak

TABLE 3.5.--Continued

Subject	Description
	v5=3 = lean trim v5=4 = medium trim
Production activities used are identified by: k5=1,2,3,4,5,6,7	k5=1 = make hamburger from primal cuts obtained from 900 lb. fed animal k5=2 = make hamburger from primal cuts obtained from 1100 lb. fed animal k5=3 = make hamburger from primal cuts obtained from 1200 lb. fed animal k5=4 = make hamburger from primal cuts obtained from 1300 lb. fed animal k5=5 = make hamburger from primal cuts obtained from yearling k5=6 = make hamburger from primal cuts obtained from 1 1/2 year old k5=7 = make hamburger from primal cuts obtained from culls
Product forms sold are identified by: u=1,2,3	u=1 = hamburger u=2 = roast u=3 = steak

TABLE 3.6 VARIABLE DEFINITIONS

Variables	Description
$f_j(Y)$	represents the market level inverse demand system for beef in the jth demand region.
$P_{j,u}$	represents the price received for beef product u consumed away from the home (the hotel, restaurant, and institutional trade) in demand region j.
$AY_{j,u}$	the quantity (cwt/year) of beef product u consumed away from the home in demand region j.
P_u	represents the price received for beef product u exported to other countries.
EY_u	represents the quantity (cwt) of beef product u exported on an annual basis.
rd_i	the price of dairy culls in the ith supply region.
ZD_i	the quantity (head) of dairy culls in the ith supply region utilized in the beef production system.
$r_{1,i,u1}$	the price of weaned beef calves (u1=1) or beef culls (u1=2) in supply region i.
$q_{1,i,k1}$	the level (head) of breeding herd activity k1 utilized in region i.
$Z_{1,i,u1}$	quantity (head) of weaned beef calves and beef culls in region i utilized in the beef production system.
$r_{2,i,k2}$	the cost ($/hd) of stockering activity k2 in supply region i.
$q_{2,i,k2}$	the level (head of cattle) of stockering activity k2 utilized in region i.
$r_{3,i,k3}$	the cost ($/head) of feeding activity k3 in region i.

$q_{3,i,k3}$	the level (head of cattle) of feeding activity k3 utilized in region i.
$r_{4,i,l}$	the cost ($/head) of slaughtering and producing boxed beef in plant l in supply region i.
$q_{4,i,l,k4}$	the level (head of cattle) of slaughtering activity k4 utilized in plant l in supply region i.
$r_{5,i,l}$	the cost ($/cwt.) of manufacturing hamburger in plant l in region i.
$q_{5,i,l,k5}$	the level (cwt.) of the k5 hamburger production activity utilized in plant l in supply region i.
$T_{i,i',u1}$	cost of transporting weaned calves(u1=1) or beef culls (u1=2) from supply region i to supply region i'.
$X_{2,i,i',u1=1}$	number of weaned calves (u1=1) in supply region i transported to region i' to be utilized in stockering activities.
$X_{3,i,i',u1=1}$	number of weaned calves (u1=1) transported from region i to region i' to be utilized in feeding activities.
$T_{i,i',u2}$	cost of transporting stockered cattle (u2=yearling or 1-1/2 year old) from supply region i to supply region i'.
$X_{3,i,i',u2}$	number of stockered cattle,(u2=yearling or 1-1/2 year old) transported from region i to region i' to be utilized in feeding activities.
$X_{4,i,i',l,u2,v4}$	head of stockered cattle (u2=yearling or 1-1/2 year old) transported from region i to be slaughtered in plant l in region i'.
$T_{i,i',uD}$	cost of transporting culls (uD=dairy) from supply region i to supply region i'.
$X_{4,i,i',l,u1=2,v4=7}$	number of beef culls (u1=2) transported from region i to be slaughtered in plant l in region i'.

$X_{4,i,i',l,uD=1,v4=7}$	number of dairy culls (uD=1) shipped for slaughter from region i to plant l in region i'.
$T_{i,i',u3}$	cost of transporting fed beef (u3=900 lbs., 1100 lbs., 1200 lbs., or 1300 lbs.) from supply region i to supply region i'.
$X_{4,i,i',l,u3,v4}$	head fed beef (u3=900 lbs., 1100 lbs., 1200 lbs., or 1300 lbs.) transported from region i to plant l in region i'.
$TI_{j,u=1}$	cost of transporting imported beef (u=hamburger) to demand region j.
$XI_{j,u=1}$	quantity of hamburger (u=1) imported to demand region j.
$TE_{i,u}$	cost of transporting exported beef (u=roast or steak) from supply region i to export markets.
$XE_{i,u}$	quantity of beef products (u=steak or roast) exported from supply region i.
$T_{i,j,u}$	cost of transporting beef products (u=hamburger, roast or steak) from supply region i to demand region j.
$X_{i,j,u}$	quantity of beef products (u=hamburger, roast or steak) shipped from supply region i to demand region j.
$M_{j,u}$	marketing margin ($/cwt.) for beef product u=hamburger, roast or steak) in demand region j.
$Y_{j,u}$	quantity (lbs./month) of beef product u consumed at home in demand region j.
I_j	quantity (cwt.) of hamburger available for importation.
$RIC_{j,u}$	quantity of beef product u consumed away from home in demand region j.
$Z_{i,u}$	quantity (cwt.) of beef product u sold in supply region i.
$Z_{4,i,l,u4,k4}$	quantity (cwt.) of primal cut u4 produced in plant l in supply region i from production activity k4.

$Z_{4,i,l,u4}$	quantity (cwt.) of primal cuts (u4=roast or steak) in region i allocated to sales activity.
$Z_{5,i,l,u4,v5}$	quantity (cwt.) of primal cuts (u4=roast, steak, lean trim or medium trim) in region i allocated to hamburger activity.
$a_{5,i,v5}$	the percentage of fat found in primal cut v5 used in the hamburger activity in supply region i.
$c_{5,i,l,v5,k5}$	quantity (cwt.) of primal cut v5 used by one unit of hamburger production activity k5 in plant l.
FAT_i	the maximum percentage of fat permitted in hamburger in supply region i.
$qA_{l,i}$	head of cattle slaughtered in plant l in supply region i.
$TCAP_{l,i}$	capacity (head of cattle) of slaughter plant l in supply region i.
$d_{4,i,l,u4,k4}$	quantity (cwt.) of primal cut u4 produced by one unit of the k4th slaughter activity of plant l in supply region i.
$c_{4,i,l,v4,k4}$	quantity (head) of cattle used by one unit of production activity k4 in plant l in supply region i.
$s_{i,i'}$	adjustment to live animal numbers due to shrinkage during transit from supply region i to supply region i'.
$s_{i,j}$	adjustment to final beef product weights due to shrinkage during transit from supply region i to demand region j.
$Z_{4,i,l,v4}$	quantity (head) of live animal v4 slaughtered in plant l in region i.
$Z_{3,i,u3}$	head of fed cattle u3 produced in supply region i.
$Z_{3,i,v3}$	head of live animal v3 placed on feedlots in supply region i.

$d_{3,i,u3,k3}$	quantity (head) of fed cattle produced by one unit of feeding activity k3 in supply region i.
$c_{3,i,v3,k3}$	quantity (head) of live animals v3 used by one unit of feeding activity k3 in supply region i.
$Z_{2,i,u2}$	head of stockered cattle u2 produced in supply region i.
$Z_{2,i,v2}$	head of live animal v2 used in stockering activities in supply region i.
$d_{2,i,u2,k2}$	quantity (head) of stockered cattle produced by one unit of stockering activity k2 in supply region i.
$c_{2,i,v2,k2}$	quantity (head) of live animals v2 used by one unit of stockering activity k2 in supply region i.
$Z_{1,i,u1}$	head of weaned calves or culls (u1=1 or 2) produced by breeding and maintenance activities in supply region i.
$Z_{0,i,v1}$	head of breeding stock used in breeding and maintenance activities in supply region i.
$d_{1,i,u1,k1}$	quantity (head) of weaned calves (u1=1) or culls (u1=2) produced by one unit of breeding (k1=1) and maintenance (k1=2) activities in supply region i.
$c_{1,i,v1,k1}$	quantity (head) of breeding stock v1 used by one unit of breeding (k1=1) or maintenance (k1=2) activity in supply region i.
ZD_i	quantity of dairy culls from supply region i utilized.
$DAIRY_i$	dairy cull supply in region i.

The Objective Function

$$\max NSB = \sum_{j=1}^{4} \int_{L} f(Y)dy_1 \cdots dy_3 + \sum_{j=1}^{4}\sum_{u=1}^{3} P_{ju}Ay_{ju}$$

$$+ \sum_{u=2}^{3} P_u EY_u - \sum_{i=1}^{5} rd_i ZD_i$$

$$- \sum_{i=1}^{5}\sum_{u1=1}^{2} r_{1,i,u1} Z_{1,i,u1}$$

$$- \sum_{i=1}^{5}\sum_{k2=1}^{2} r_{2,i,k2} q_{2,i,k2}$$

$$- \sum_{i=1}^{5}\sum_{k3=1}^{6} r_{3,i,k3} q_{3,i,k3}$$

$$- \sum_{i=1}^{5}\sum_{k3=1}^{5}\sum_{k4=1}^{7} r_{4,i,1} q_{4,i,1,k4}$$

$$- \sum_{i=1}^{5}\sum_{l=1}^{5}\sum_{k5=1}^{4} r_{5,i,1} q_{5,i,1,k5}$$

$$- \sum_{i=1}^{5}\sum_{i'=1}^{5} T_{i,i',u1=1} X_{2,i,i',u1=1}$$

$$- \sum_{i=1}^{5} \sum_{i'=1}^{5} T_{i,i',u1=1} \; X_{3,i,i',u1=1}$$

$$- \sum_{i=1}^{5} \sum_{i'=1}^{5} \sum_{u2=1}^{2} T_{i,i',u2} \; X_{3,i,i',u2}$$

$$- \sum_{i=1}^{5} \sum_{i'=1}^{5} \sum_{l=1}^{5} T_{i,i',l,u1=2} \; X_{4,i,i',l,u1=2,v4=7}$$

$$- \sum_{i=1}^{5} \sum_{i'=1}^{5} \sum_{l=1}^{5} \sum_{u2=1}^{2} \sum_{v4=5}^{6} T_{i,i',u2} \; X_{4,i,i',l,u2,v4}$$

$$- \sum_{i=1}^{5} \sum_{i'=1}^{5} \sum_{l=1}^{5} \sum_{u3=1}^{4} \sum_{v4=1}^{4} T_{i,i',u3} \; X_{4,i,i',l,u3,v4}$$

$$- \sum_{i=1}^{5} \sum_{i'=1}^{5} \sum_{l=1}^{5} T_{i,i',uD} \; X_{4,i,i',l,uD,v4=7}$$

$$- \sum_{j=1}^{4} (TI_{j,u=1} + M_{j,u=1}) \; XI_{j,u=1}$$

$$- \sum_{i=1}^{5} \sum_{u3=2}^{3} TE_{i,u} \; XE_{i,u}$$

$$- \sum_{i=1}^{5} \sum_{j=1}^{4} T_{i,j,u} \; X_{i,j,u}$$

The objective function is maximizing the area underneath the demand curves in all the demand regions minus the total cost of activities at each stage of production and total transportation costs. It also takes account of expenditures on away from home consumption and the cost of importing beef.

Constraints

The maximization of the objective function is subject to a number of constraints. The constraints embody the production activities, transportation activities and the equilibrium conditions for a competitive market. They are expressed as follows:

1. Dairy cull supply constraint.

$$ZD_i - DAIRY_i \leq 0; \qquad i=1,\cdots,5;$$

This constraint ensures that the number of dairy culls utilized in region i is no greater than the number of dairy culls available in region i.

2. Dairy cull transfer constraint.

$$-ZD_i + \sum_{i'=1}^{5} \sum_{l=1}^{5} X_{4,i,i',l,uD} \leq 0; \qquad i=1,\cdots,5; \quad uD=1;$$

This constraint guarantees that the number of dairy culls transferred from region i ($X_{4,i,i',l,uD}$) is less than

or equal to the number of dairy culls utilized in region i ($-ZD_i$).

3. Maintenance of breeding herd constraint.

$$-Z_{o,i,v1} + \sum_{k1=1}^{2} c_{1,i,v1,k1} \cdot q_{1,i,k1} \leq 0; \qquad \begin{array}{l} i=1,\cdots,5; \\ v1=1; \\ k1=1,2; \end{array}$$

This constraint ensures that the number of cows utilized in the replacement and breeding activities ($c_{1,i,v1,k1} \cdot q_{1,i,k1}$) in region i is less than or equal to the number of cows available in region i ($Z_{o,i,v1}$).

4. Weaned calf and cull production constraint.

$$Z_{1,i,u1} - \sum_{k1=1}^{2} d_{1,i,u1,k1} \cdot q_{1,i,k1} \leq 0; \qquad \begin{array}{l} i=1,\cdots,5; \\ u1=1,2; \end{array}$$

This constraint ensures that the number of weaned calves or culls produced in region i ($d_{1,i,u1,k1} \cdot q_{1,i,k1}$) is greater than or equal to the available supply of weaned calves or culls in region i ($Z_{1,i,u1}$).

5. Beef cull transfer constraint.

$$-Z_{1,i,u1=2} + \sum_{i'=1}^{5} \sum_{l=1}^{5} X_{4,i,i',l,u2=2} \leq 0; \qquad i=1,\cdots,5;$$

In this constraint the cattle culled from the breeding herd are transferred to the slaughter-processing stage. It ensures that the number of beef culls transferred from region i to the slaughtering stage ($X_{4,i,l,u1=2}$) is less than or equal to the available supply of beef culls in region i ($Z_{1,i,u1=2}$).

6. Weaned calf transfer constraint.

$$-Z_{1,i,u1=1} + \sum_{i'=1}^{5} X_{2,i,i',u1=1} + \sum_{i'=1}^{5} X_{3,i,i',u1=1} \leq 0; \qquad i=1,\cdots,5;$$

In this constraint weaned calves in region i are transferred to either the stocker or finishing stages. It guarantees that the number of weaned calves transported from region i to the stocker ($X_{2,i,i'=1}$) and finishing stages ($X_{3,i,i',u1=1}$) is less than or equal to the supply of weaned calves in region i ($Z_{1,i,u1=1}$).

7. The receipt of weaned calves into the stockering stage constraint.

$$-\sum_{i'=1}^{5} s_{i,i'} \cdot X_{2,i,i',u1=1} + Z_{2,i,v2} \leq 0; \qquad i=1,\cdots,5; \quad v2=1;$$

This constraint assembles weaned calves for use in stockering activities in region i. It ensures that the number of weaned calves assembled for use in stockering activities ($Z_{2,i,v2}$) is no greater than the number of weaned calves shipped to the stockering stage in region i times a shrinkage parameter which adjusts the number of weaned calves shipped for injury and death in transit ($s_{i,i'} \cdot X_{2,i,i',u1=1}$).

8. The utilization of calves in the stockering stage constraint.

$$-Z_{2,i,v2} + \sum_{k2=1}^{2} c_{2,i,v2.k2} \cdot q_{2,i,k2} \leq 0; \qquad i=1,\cdots,5; \quad v2=1; \quad k2=1,2;$$

This constraint ensures that the number of weaned calves utilized in the stockering activity in region i ($c_{2,i,v2,k2} \cdot q_{2,i,k2}$) is no greater than the supply of stocker calves in region i.

9. The stocker output constraint.

$$Z_{2,i,u2} - \sum_{k2=1}^{2} d_{2,i,u2,k2} \cdot q_{2,i,k2} \leq 0; \quad i=1,\cdots,5; \; u2=1,2;$$

This constraint ensures that the number of stockered cattle produced in region i ($d_{2,i,u2,k2} \cdot q_{2,i,k2}$) is greater than or equal to the available supply of stockered cattle in region i ($Z_{2,i,u2}$).

10. The transfer of stockered cattle constraint.

$$- Z_{2,i,u2} + \sum_{i'=1}^{5} X_{3,i,i',u2} + \sum_{i'=1}^{5} \sum_{l=1}^{5} X_{4,i,i',l,u2} \leq 0; \quad i=1,\cdots,5; \; u2=1,2; \; k2=1,2;$$

This constraint transfers stockered cattle in region i to either the finishing or slaughter stages. It guarantees that the number of stockered cattle transported from region i to the finishing ($X_{3,i,i',u3}$) and slaughter stages ($X_{4,i,i',u3}$) is less than or equal to the available supply of stockered cattle in region i ($Z_{2,i,u2}$).

11. The receipt of weaned calves into the finishing stage constraint.

$$-\sum_{i'=1}^{5} s_{i,i'} \cdot X_{3,i,i',u1=1} + Z_{3,i,v3=1} \leq 0; \qquad i=1,\cdots,5;$$

This constraint collects weaned calves for use in the finishing stage in region i. It ensures that the number of weaned calves collected for use in feeding activities ($Z_{3,i,v3=1}$) is no greater than the number of weaned calves shipped to the finishing stage in region i times a shrinkage parameter which adjusts the number of weaned calves shipped for injury and death in transit ($s_{i,i'} \cdot X_{3,i,i',u1=1}$).

12. The receipt of stockered cattle into the finishing stage constraint.

$$-\sum_{i'=1}^{5} s_{i,u'} \cdot X_{3,i,i',u2} + Z_{3,i,v3} \leq 0; \qquad \begin{array}{l} i=1,\cdots,5; \\ u2=1,\ v3=2; \\ u2=2,\ v3=3; \end{array}$$

This constraint collects stockered cattle for use in the finishing stage in region i. It ensures that the number of stockered cattle collected for use in feeding activities ($Z_{3,i,v3}$) is no greater than the number of stockered cattle shipped to the finishing stage in

region i times a shrinkage parameter which adjusts the number of stockered cattle shipped to region i for injury and death in transit ($s_{i,i'} \cdot X_{3,i,i',v3}$).

13. The utilization of cattle in the finishing stage constraint.

$$- Z_{3,i,v3} + \sum_{k3=1}^{4} c_{3,i,v3,k3} \cdot q_{3,i,k3} \leq 0; \qquad \begin{matrix} i=1,\cdots,5; \\ v3=1,\cdots,3; \end{matrix}$$

This constraint ensures that the head of cattle utilized in feeding activities in region i ($c_{3,i,v3,k3} \cdot q_{3,i,k3}$) is no greater than the supply of cattle for finishing in region i ($Z_{3,i,v3}$).

14. The finishing stage output constraint.

$$Z_{3,i,u3} - \sum_{k3=1}^{4} d_{3,i,u3,k3} \cdot q_{3,i,k3} \leq 0; \qquad \begin{matrix} i=1,\cdots,5; \\ u3=1,\cdots,4; \end{matrix}$$

This constraint ensures that the number of finished cattle produced in region i ($d_{3,i,u3,k3} \cdot q_{3,i,k3}$) is greater than or equal to the available supply of finished cattle in region i ($Z_{3,i,u3}$).

15. The transfer of finished or fed cattle constraint.

$$- Z_{3,u,u3} + \sum_{i'=1}^{5} \sum_{l=1}^{5} X_{4,i,i',l,u3} \leq 0; \qquad \begin{matrix} i=1,\cdots,5; \\ u3=1,\cdots,4; \end{matrix}$$

This constraint transfers finished cattle in region i to the slaughter stage. It guarantees that the number of fed cattle transported from region i to the slaughter stage ($X_{4,i,i',l,u3}$) is less than or equal to the supply of finished cattle in region i ($Z_{3,i,u3}$).

16. The receipt of culls into the slaughter stage constraint.

$$Z_{4,i,l,v4=7} - \sum_{i=1}^{5} s_{i,i'} \cdot X_{4,i,i',l,u1=2}$$

$$- s_{i,i'} \cdot X_{4,i,i',l,uD} \leq 0; \qquad \begin{matrix} i=1,\cdots,5; \\ l=1,\cdots,5; \end{matrix}$$

This constraint assembles culls for slaughter in region i. It ensures that the number of culls assembled for use in slaughtering activities ($Z_{4,i,l,v4=7}$) is no greater than the number of beef culls shipped to the slaughtering stage in region i times a shrinkage parameter which adjusts the number of weaned calves shipped for injury and death while in transit ($s_{i,i'} \cdot X_{4,i,i',l,u1=2}$) and the number of dairy culls shipped to the slaughtering stage in region i times a shrinkage parameter ($s_{i,i'} \cdot X_{4,i,i',l,u1=2}$).

17. The receipt of stockered cattle into the slaughter stage constraint.

$$Z_{4,i,l,v4} - \sum_{i'=1}^{5} s_{i,i'} \cdot X_{4,i,i',l,u2} \leq 0; \qquad \begin{array}{l} i=1,\cdots,5; \\ l=1,\cdots,5; \\ v4=5,6; \\ u2=1,2; \end{array}$$

This constraint assembles stockered cattle for slaughter in region i. It ensures that the number of stockered cattle assembled for use in slaughter activities ($Z_{4,i,l,v4}$) is no greater than the number of stockered cattle shipped to the slaughter stage in region i times a shrinkage parameter which adjusts the number of stockered cattle shipped to region i for injury and death in transit ($s_{i,i'} \cdot X_{4,i,i',l,u2}$).

18. The receipt of finished cattle into the slaughter stage constraint.

$$Z_{4,i,l,v4} - \sum_{i'=1}^{5} s_{i,i'} X_{4,i,i',l,u3} \leq 0; \qquad \begin{array}{l} i=1,\cdots,5; \\ l=1,\cdots,5; \\ v4=1,\cdots,4; \\ u3=1,\cdots,4; \end{array}$$

This constraint assembles finished cattle for slaughter in region i. It ensures that the number of fed cattle assembled for use in slaughter activities ($Z_{4,i,l,v4}$) is no greater than the number of fed cattle shipped to the

slaughter stage in region i times a shrinkage parameter which adjusts the number of fed cattle shipped to region i for injury and death in transit ($s_{i,i'} \cdot X_{4,i,i',l,u3}$).

19. The utilization of cattle in the slaughter stage constraint.

$$Z_{4,i,l,v4} - \sum_{k4=1}^{7} C_{4,i,i',l,v4,k4} \cdot q_{4,i,l,k4} \leq 0; \quad \begin{array}{l} i=1,\cdots,5; \\ l=1,\cdots,5; \\ v4=1,\cdots,7; \end{array}$$

This constraint ensures that the quantity of cattle slaughtered in plant l ($c_{4,i,l,v4,k4} \cdot q_{4,i,l,k4}$) is no greater than plant i's supply of slaughter cattle ($Z_{4,i,l,v4}$).

20. The slaughter activity output constraint.

$$Z_{4,i,l,u4,} - \sum_{k4=1}^{7} d_{4,i,l,u4,k4} \cdot q_{4,i,l,k4} \leq 0; \quad \begin{array}{l} i=1,\cdots,5; \\ l=1,\cdots,5; \\ u4=1,\cdots,5; \end{array}$$

This constraint guarantees that the number of primal cuts produced by plant l ($d_{4,i,l,u4,k4} \cdot q_{4,i,l,k4}$) is greater than or equal to the available supply of primal cuts in plant l ($Z_{4,i,l,u4}$).

21. The slaughter of cattle in meatpacking plant constraint.

$$\sum_{k4=1}^{7} q_{4,i,l,k4} - Q_{A,i,l} = 0; \qquad \begin{matrix} i=1,\cdots,5; \\ l=1,\cdots,5; \end{matrix}$$

This constraint accounts for the head of cattle slaughtered in plant l in region i.

22. The slaughter capacity constraint.

$$QA_{i,l} - TCAP_{i,l} \leq 0; \qquad \begin{matrix} i=1,\cdots,5; \\ l=1,\cdots,5; \end{matrix}$$

This constraint requires that the quantity of cattle slaughtered does not exceed plant capacity.

23. The transfer of primal cuts to sale and hamburger processing activities constraint.

$$-Z_{4,i,l,u4} + \delta Z_{4,i,l,u4} + \delta' Z_{5,i,l,v5} \leq 0;$$

$$\begin{matrix} i=4,\cdots,5; & l=1,\cdots,5; \\ u4=1,\cdots,4; & v5=1,\cdots,4; \\ \delta = 1 \text{ if } u4=1,2 \\ \quad\; 0 \text{ if } u4=3,4,5 \\ \delta' = 1 \text{ if } v5=1,\cdots,4; \\ \quad\; 0 \text{ if } v5=5; \end{matrix}$$

This constraint allocates the quantity of primal cuts produced in plant l to sales or hamburger processing activities. It ensures that the quantity of primal

cuts allocated to sales and hamburger processing ($Z_{4,i,l,v4} + Z_{5,i,l,v5}$) is less than or equal to the quantity of primal cuts available in plant l ($Z_{4,i,l,u4,k4}$).

24. Regional supply of steaks and roasts constraint.

$$\sum_{l=1}^{5} Z_{4,i,l,u4} + Z_{i,u} \; 0; \qquad \begin{array}{l} i=1,\cdots,5; \\ u4=1,\ u=2; \\ u4=2,u=3; \end{array}$$

This constraint assembles all the steaks and roasts allocated to the sales activity in the meatpacking plants in region i ($Z_{4,i,l,u4}$) at a single distribution center. It guarantees that the quantity of steaks and roasts available for distribution in region i ($Z_{i,u}$) is no greater than the quantity of steaks and roasts allocated to sale by the meatpacking plants in region i.

25. Utilization of primal cuts in the production of hamburger constraint.

$$- Z_{5,i,l,v5} + \sum_{k5=1}^{4} c_{5,i,l,v5,k5}\, q_{5,i,l,k5} \leq 0; \qquad \begin{array}{l} i=1,\cdots,5; \\ l=1,\cdots,5; \\ v5=1,\cdots,4; \end{array}$$

This constraint ensures that the quantity of primal cuts used to produce hamburger in plant l ($c_{5,i,l,v5,k5} \cdot q_{5,i,l,k5}$) is less than or equal to the quantity of primal

cuts allocated to the hamburger processing activity in plant 1 ($Z_{5,i,1,v5}$).

26. The hamburger processing constraint.

$$\sum_{k5=1}^{4} \sum_{l=1}^{5} q_{5,i,l,k5} + Z_{i,u=1} \leq 0; \qquad i=1,\cdots,5;$$

This constraint ensures that the quantity of hamburger in region i ($Z_{i,u=1}$) is no greater than the quantity of hamburger produced in the meatpacking plants in region i ($\Sigma_{k5}\Sigma_{1}\ q_{5,i,l,k5}$).

27. Hamburger fat content constraint.

$$\sum_{k5=1}^{4} \sum_{l=1}^{5} a_{5,i,k5} \cdot q_{5,i,l,k5} - FAT_i \cdot Z_{i,u=1} \leq 0; \qquad i=1,\cdots,5;$$

This constraint ensures that percentage of fat by weight contained in hamburger produced in region i does not exceed 27%.

28. The transfer of boxed beef constraint.

$$\sum_{j=1}^{4} X_{i,j,u} + XE_{i,u} - Z_{i,u} \leq 0; \qquad \begin{matrix} i=1,\cdots,5; \\ u=1,\cdots,3; \end{matrix}$$

This constraint transfers box beef cuts from supply region i to domestic and foreign markets. It ensures

that the quantity of boxed beef cuts transported from supply region i ($X_{i,j,u} + XE_{i,u}$) is less than or equal to the supply of boxed beef cuts in region i ($Z_{i,u}$).

29. Hamburger import constraint.

$$\Sigma_j \; X_{j,u-1} - I \leq 0; \qquad u=1;$$

This constraint ensures that the quantity of hamburger imported is less than or equal to an exogenously determined supply of imported hamburger.

30. Beef consumption constraint.

$$- \delta XI_{j,u-1} - \Sigma_i \; s_{i,j} \; X_{i,j,u} + (.12) \; Y_{j,u} + AY_{j,u} \leq 0;$$

$u=1,2,3;$
$j=1,\cdots,4;$
$\delta = 1$ if $u=1$
0 if $u=2,3;$

This constraint ensures that the quantity of fresh beef consumed at and away from the home ($Y_{j,u} + AY_{j,u}$) in demand region j is less than or equal to the quantity of foreign and domestically produced transported to region j ($X_{i,j,u} + XF_{j,u-1}$).

31. Away from home consumption constraint.

$$- AY_{j,u} + HRI_{j,u} = 0;$$

$j=1,\cdots,4;$
$u=1,\cdots,3;$

This constraint requires that away from home consumption of beef in region j equal the away from home demand for beef.

CHAPTER 4
SPECIFICATION OF AN INVERSE DEMAND SYSTEM FOR FRESH MEATS

The purpose of this chapter is to specify a system of demand equations for fresh meats to be used in the programming model. The demand system needs to satisfy the restrictions placed on it by both economic theory and the programming model.

The first section of the chapter lays out the conditions the demand system needs to satisfy in order for it to be incorporated into the programming model (Table 4.1). In the second section of the chapter a demand system for fresh meats which is consistent with the conditions established is derived. Characteristics of the data, the estimation procedure used and the estimated system are discussed in the third section. In the final section the demand system to be used in the programming model and a description of the steps taken to incorporate the estimated demand system into the programming model are discussed.

Criteria for Selecting a Demand System to be Used in the Programming Model

The first condition which the demand system must meet in order to be used in the programming model is that it be specified in price-dependent or inverse form. This

TABLE 4.1. THE CRITERIA USED FOR SELECTING AN APPROPRIATE SYSTEM OF DEMAND EQUATIONS.

1. They must be specified in price-dependent form.
2. They must satisfy the integrability conditions of the price endogenous mathematical programming model.
   a. Negative definite Jacobian matrix
   b. Symmetric cross-quantity effects
3. They must satisfy nonseparability of preferences among the various meat products.

condition is imposed by the formulation of the programming model being used. By specifying the demand system in price-dependent form it is much easier to formulate the programming model and to make economic interpretations.

In demand theory, the demand system is usually derived by assuming that prices and income are given and that it is the quantity consumed which is adjusted by consumers in order to maximize their utility. As a result the consumer's demand system is specified in quantity-dependent form. Fortunately, one of the basic results obtained through the use of duality theory is that the consumer's preferences can be represented by either the quantity-dependent demand system or the associated inverse demand system. Anderson (1980) has further shown that the inverse demand systems have properties analogous to the properties of the quantity-dependent demand systems.

In many cases the use of an inverse demand system is just a matter of expedience with regards to the modeling effort. There being no reason to represent the demand relationship in inverse form other than to make the formulation of the programming model simpler and easier to interpret in an economic sense (see Takayama and Judge, 1971). However, for a product such as beef, the production decisions are made long before the final product is available to consumers. This implies that at any given point in time the supply of beef is fixed, and it is the price of

beef which must adjust in order to achieve market equilibrium. Given this it can then be argued that the demand for beef should be specified in its inverse form, not only because it is more convenient for modeling purposes, but because it properly represents the manner in which equilibrium in the market for beef is determined.

The second condition which the demand system must fulfill is that it satisfy the integrability conditions of the programming model. The integrability conditions require that the Jacobian matrix of the demand equations be negative definite and have symmetric cross-quantity effects. As discussed in Chapter 2 the integrability conditions ensure that a unique solution exists.

A third condition which must be satisfied by the demand system is that it reflect the nonseparability of preferences for meat products by species. The reason for this assumption about the separability of consumers' preferences for fresh meat is discussed in greater detail in the next section.

In addition to the conditions just discussed it is important that the demand system reflect regional differences in consumer preferences for meat. This is based on the assumption that differences in the levels of fresh meat consumed between regions is determined not only by differences in population and level of income between regions, but also by differences in their customs and traditions.

Finally, given the controversy over whether a shift in consumer preferences for meat has occurred the data used to estimate the demand system should come from the period after the change in the structure in the demand for meat is believed to have occurred. This will ensure that the estimated parameters will reflect the current demand structure for fresh meat.

The Two-Stage Budgeting Process and the Representation of Consumer Preferences

According to demand theory the fundamental decision facing consumers is how to allocate their income among the available goods so as to maximize their utility. This decision is determined by the consumer's preferences, the prevailing commodity prices and the consumer's income. While the consumer's preferences are unobservable they can be represented by a system of demand equations which relates the utility maximizing level of consumption to prices and income.

Demand theory assumes that consumers know and take into consideration all commodities available when making their consumption decisions. This implies that the system of demand equations should contain all commodities. However, empirical demand equations only contain the commodities of interest and a small subset of related commodities. One reason for this is that it is impractical to estimate a demand system which contains all commodities. A second

reason for this is the realization that consumers do not take into consideration all goods when they make their expenditure decisions, but only a subset of related goods. Thus, a demand system, if appropriately defined, only needs to contain the commodities of interest in order to appropriately represent the consumer's behavior.

The two-stage budgeting process is often used to represent the consumer's decision-making process and to define the set of commodities to be included in the demand system. In the two-stage budgeting process the consumer first decides how to allocate his or her income over a broad category of goods, then in the second stage how to allocate each category's expenditures over the goods contained in them.

The two-stage budgeting process is used to construct a utility tree which shows which goods consumers take into consideration when making their expenditure decisions. The utility tree depicted in Figure 4.1 demonstrates how the two-stage budgeting process is used to select the commodities to be included in a demand system. The branches of the tree represent the budget or expenditure categories and nodes or leaves on the branches represent the commodities contained in each of the budget categories. By following along the branches of this tree one can follow the process used by the consumer when making a decision to purchase a particular good. The first leaf on the tree represents all

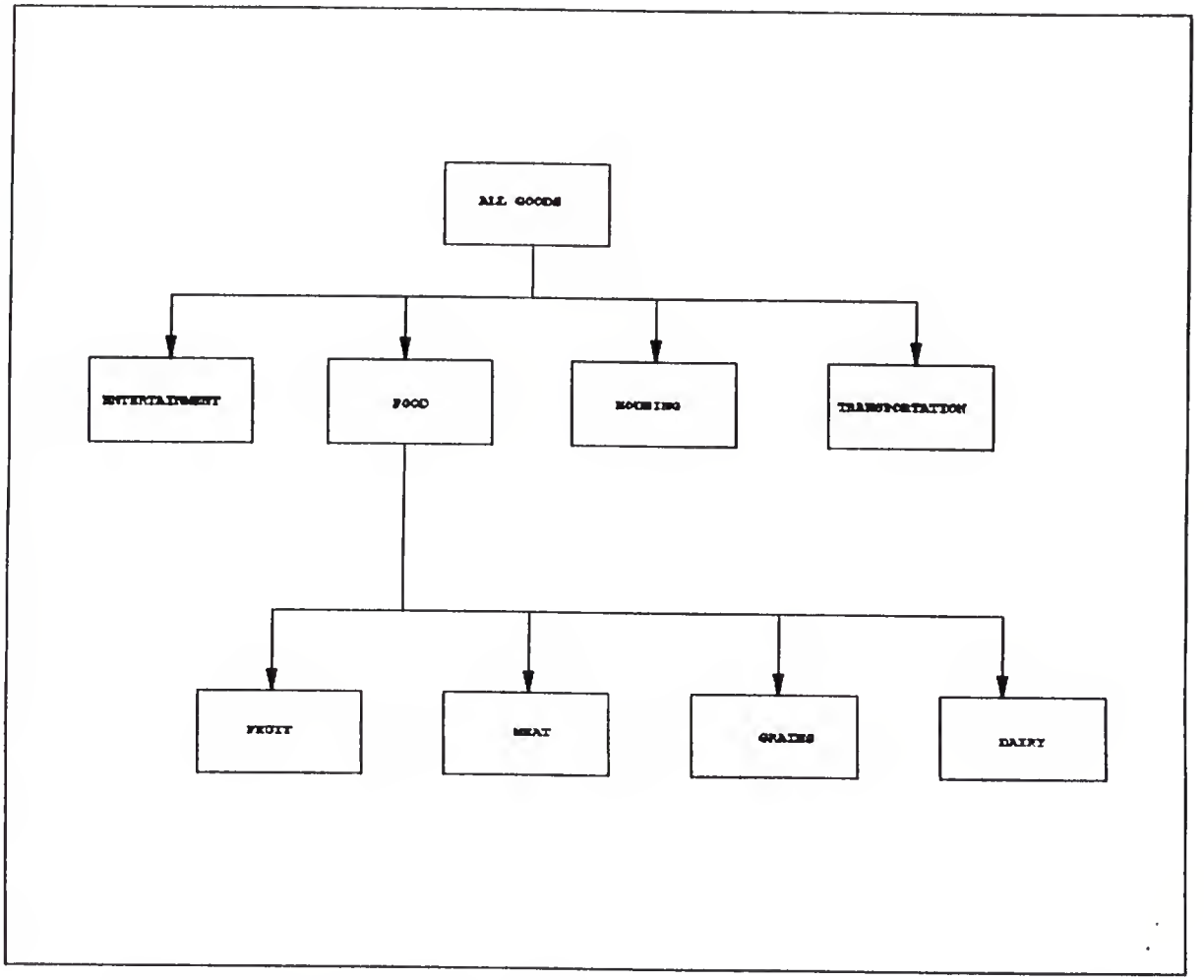

Figure 4.1. Utility tree.

available goods. At this stage the consumer decides how to allocate expenditures among housing, transportation, food, and entertainment located at the nodes at the end of each branch. Then in the next stage the consumer then decides how to allocate food expenditures among the items in the food category, such as meats, dairy products, grains, and fruit.

In order for a particular decision tree to be an appropriate representation of the consumer's budgeting process, the consumer's preferences must be weakly separable according to the branches of the decision tree. Weak separability implies that each branch of the decision tree can be defined by a separate sub-utility function. Thus, the two-stage budgeting process provides a theoretical foundation for demand systems which only contain a portion of the goods available by allowing a demand system to be derived from the sub-utility function containing the goods of interest.

There are any number of decision trees which could be used to represent consumers' decisions to purchase fresh meats. Two likely candidates are represented in the two panels found in Figures 4.2 and 4.3.

The utility tree in Figure 4.2 represents a two-stage budgeting process for fresh meat based on the animal species from which the meat comes. At the first level of

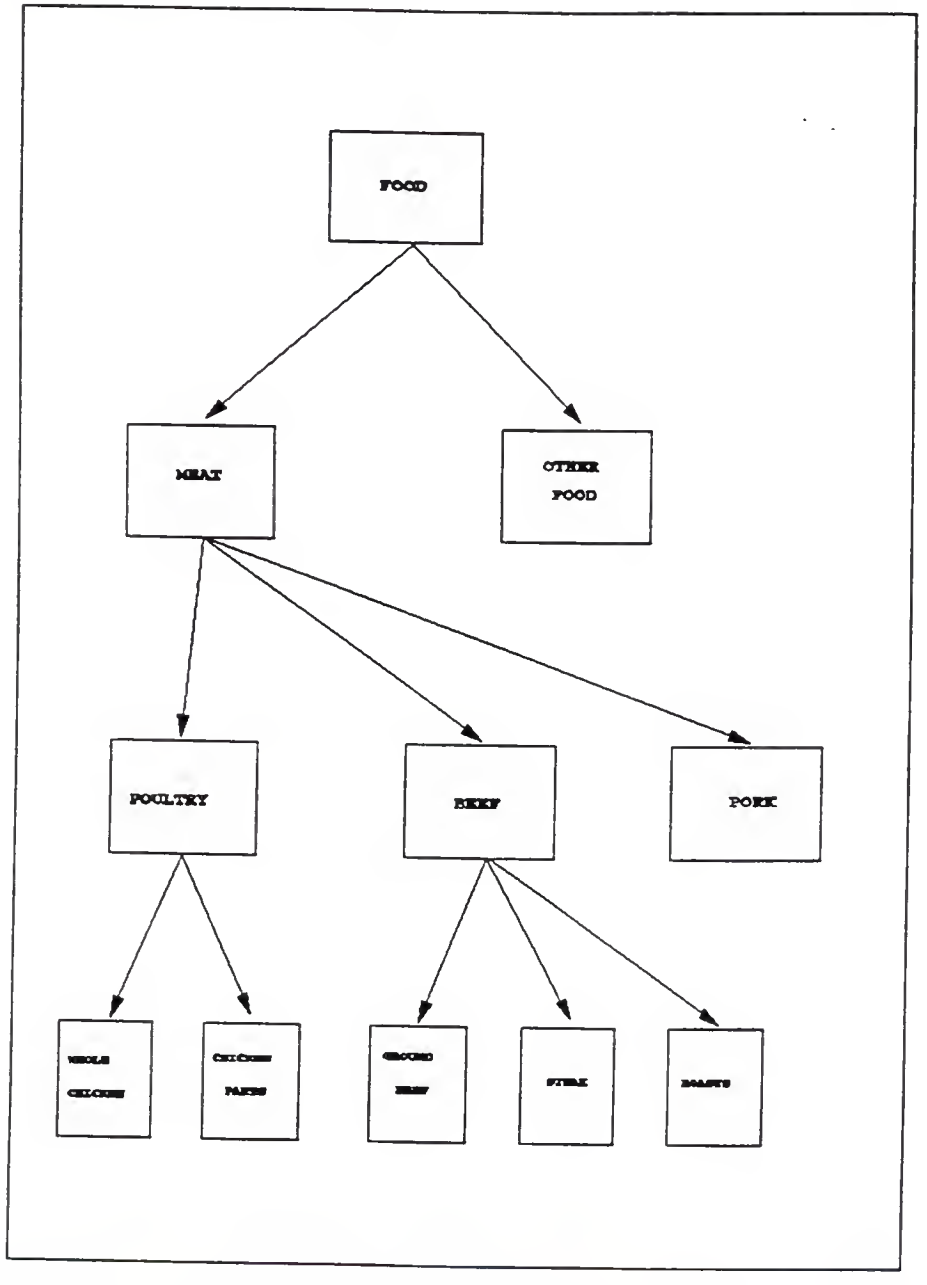

Figure 4.2. Utility tree A.

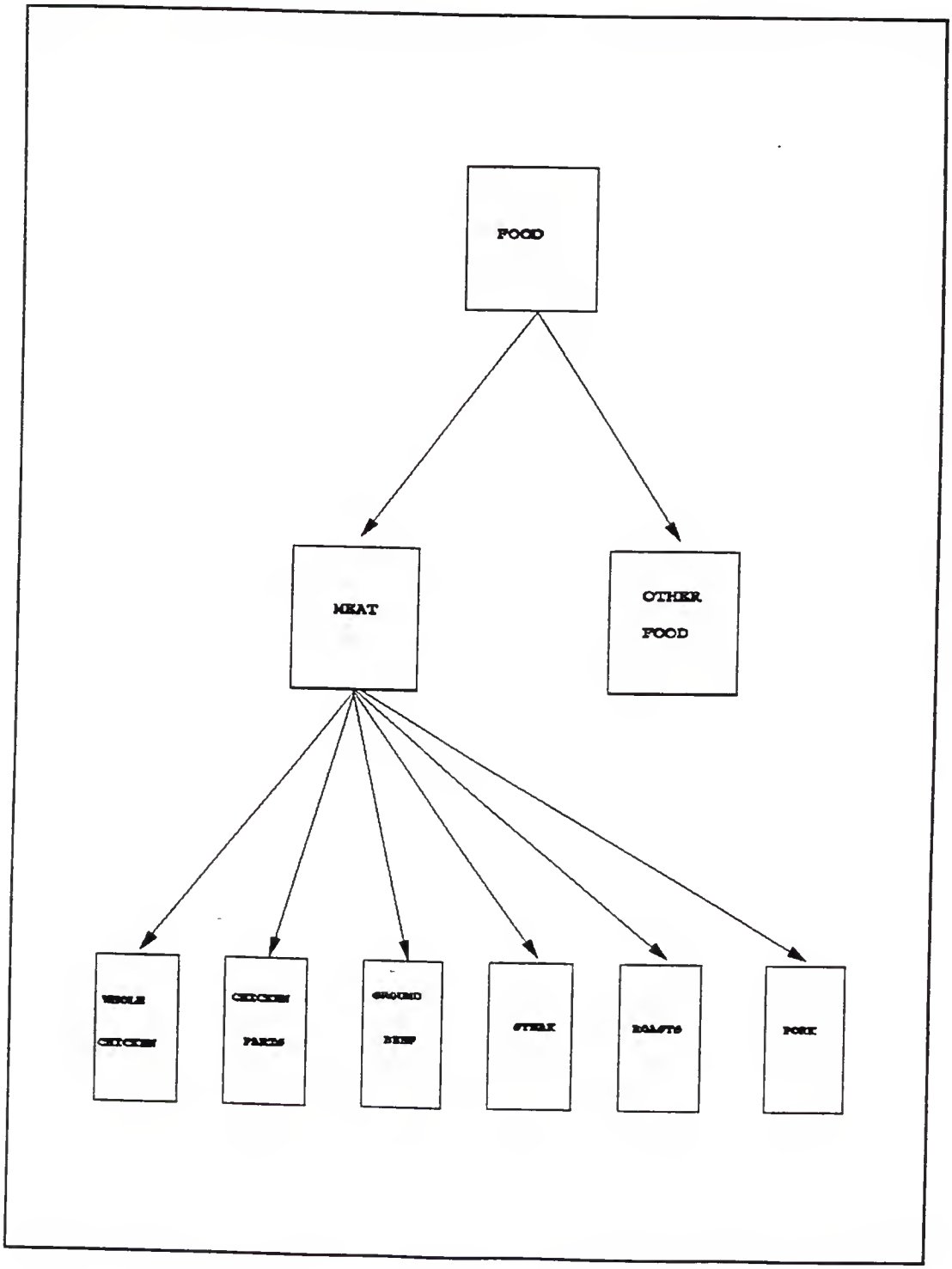

Figure 4.3. Utility tree B.

decision-making the consumer has a given level of expenditures to allocate to food. The consumer then decides how to allocate the given level of expenditure between meat and nonmeat categories. At the second level the consumer then decides the amount of expenditures for meat to allocate to the purchase of beef, pork, and poultry. At the final level of the decision tree the consumer then decides the amount of beef expenditures to spend on hamburger, steak, and roasts.

The utility tree in Figure 4.2 represents the two-stage budgeting process underlying most empirical studies of the structure of the consumer's demand for meat. To a large extent this has been simply a matter of expedience. For the most part the data on consumption of meat has been based on disappearance and not on knowledge of the amount actually purchased by consumers at the retail level. The information available is published by species. It is also argued that the assumption that consumers determine how much to spend on beef, pork and poultry before selecting the particular beef pork or poultry product they purchase reflects the way consumers budget their meat expenditures. One only need to look at the meat case at the supermarket where meat is separated by species to find corroboration of this observation.

The decision tree in Figure 4.3 represents an alternative view of the consumer's budgeting process for meats. In this case, once the consumer determines the allocation for meat expenditures then the consumer does not

make a further distinction between the different meat products based on origin of species alone. The consumer decides how much of food expenditures to allocate towards the purchase of meat, then at the next level determines the amount to spend on the various meat products represented in the diagram. This utility tree implies that consumers' preferences for meat are weakly separable while their preferences for hamburger, steaks, roasts, pork, whole chickens, and chicken parts are not.

Recent empirical evidence indicates that consumers do not make a distinction between meat products based on species of origin alone. It indicates that consumers determine how much of their food expenditures to spend on meat and then decide how much of their meat expenditures to spend on steaks, roasts, hamburger, pork, whole chickens, chicken parts and other meat products (Eales and Unnevehr, 1988) as represented by the utility tree in Figure 4.3. Thus, in order for a system of demand equations to be consistent with the decision making process of the consumer it must be specified at a level which encompasses all meat cuts, not just those of a particular species. It is a maintained assumption of this study that consumers' preferences for fresh meat are weakly separable from all other goods but not separable among the various meat products.

The Derivation of the Inverse Almost Ideal Demand System

Consider the Almost Ideal Demand System (AIDS) proposed by Deaton and Muellbauer (1980). The AIDS model was developed to test the restrictions on consumer demand derived from demand theory. As a result it is possible to impose symmetry of the substitution matrix during estimation. Furthermore, the AIDS model is specified in level form. This gives it an advantage over the Rotterdam model which is specified in first difference form because this permits it to be readily incorporated into a static programming model. The AIDS model also has the advantage that, as long as consumer's preferences are of the price independent generalized logarithmic (PIGLOG) form, it permits perfect aggregation over consumers without assuming that preferences are additive. Thus, with this particular demand system there is a theoretical justification for imposing demand restrictions based on individual behavior at the market level.

Deaton and Muellbauer (1980) derive the AIDS model by applying Shepherd's Lemma to an expenditure function. An inverse demand system analogous to the AIDS model can be derived by specifying a distance function which is dual to the expenditure function used by Deaton and Muellbauer (1980) and applying the Shepherd-Hancock Lemma. By using the distance function similar in form to the AIDS

expenditure function the properties possessed by the AIDS model are carried over into the inverse demand system.

The distance function is

$$\ln D(U,q) = a(q) + U*b(q) \tag{4.1}$$

where

$$a(q) = a_o + \sum_i \alpha_i * \ln q_i + 1/2 \sum\sum_{ij} \gamma_{ij} \ln q_i \ln q_j \tag{4.2}$$

and

$$b(q) = \beta_o \Pi q_i^{\beta_i} \tag{4.3}$$

U represents the level of utility and q is the vector of commodities consumed. D(U,q) is homogenous in q if $\Sigma\alpha_i=1$, $\Sigma_i\gamma_{ij} = \Sigma_j\gamma_{ij} = \Sigma\beta_i = 0$, and $\gamma_{ij} = \gamma_{ji}$.

The compensated share equations in quantity dependent form are derived by taking the partial derivatives of the distance function with respect to ln q_i. Resulting in

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln q_j + U\beta_i\beta_o\Pi q_i^{\beta_i} \tag{4.4}$$

The equations are functions of quantity and utility and represent the compensated inverse demand system in share equation form. If it is assumed that preferences are homothetic then it is possible to substitute real expenditures (X/P) for utility. An estimable system which does not rely on the assumption that preferences are homothetic is found by deriving an expression for utility from the distance

function, 4.1-4.3, and then substituting this expression for U in 4.4.

Utility maximization implies that D(U,q)=1 and along with 4.1-4.3 that

$$U = -(a_o + \sum_i \alpha_i * \ln q_i + 1/2 \sum\sum_{ij} \gamma_{ij} \ln q_i \ln q_j)/\beta_o \Pi q_i^{\beta_i} \qquad (4.5)$$

Substituting the result from 4.5 into 4.4 and simplifying results in

$$w_i = \alpha_i + \Sigma_j \gamma_{ij} \ln q_j - \beta_i \ln(Q) \qquad (4.6)$$

where

$\ln(Q) = a(q)$, $\Sigma_i \alpha_i = 1$, $\gamma_{ij} = \gamma_{ji}$, $\Sigma_j \gamma_{ij} = 0$ $\Sigma_i \gamma_{ij} = 0$ and

$\Sigma_i \beta_i = 0$.

The system of share equations represented by 4.6 are functions of q alone and represent the uncompensated inverse demand system. It is linear in parameters if ln(Q) is approximated by $\Sigma_k w_k \ln q_k$.

The Data

Data on the level of household expenditures on fresh meat products were obtained from the Bureau of Labor Statistics (BLS) Consumer Expenditure Survey (CES), 1982-1986. The survey is a representative sample of the U.S. population. It records the weekly expenditures of a household

over a two week period. The U.S. is divided into four regions: Northeast, South, Midwest and West (Figure 4.4). As with all household surveys a zero level of expenditures was reported for any particular commodity for many of the households. Consequently, the data were aggregated from the household level to the regional level in order to eliminate the possibility of having zero as an observation.

Expenditure levels for 22 meat products are reported in the survey which were in turn aggregated into eight categories for estimation purposes (see Table 4.2). This aggregation process used the formulas provided in the CES documentation (see Appendix A for the formulas). The new data set contains the level of average monthly household expenditure on the eight aggregate meat commodities by region.

Data on monthly prices of meat products in the four demand regions were also obtained from the BLS. The data contain the U.S. average price as well as separate regional prices for 24 meat products. The prices reported were roughly consistent with the commodity categories obtained from the expenditure survey (see Table 4.2). In the several instances where multiple prices were reported for a single expenditure category in the CES data the prices were averaged together. There were three exceptions to this procedure. In the steak category the price for porterhouse steak was not used in calculating the average price for

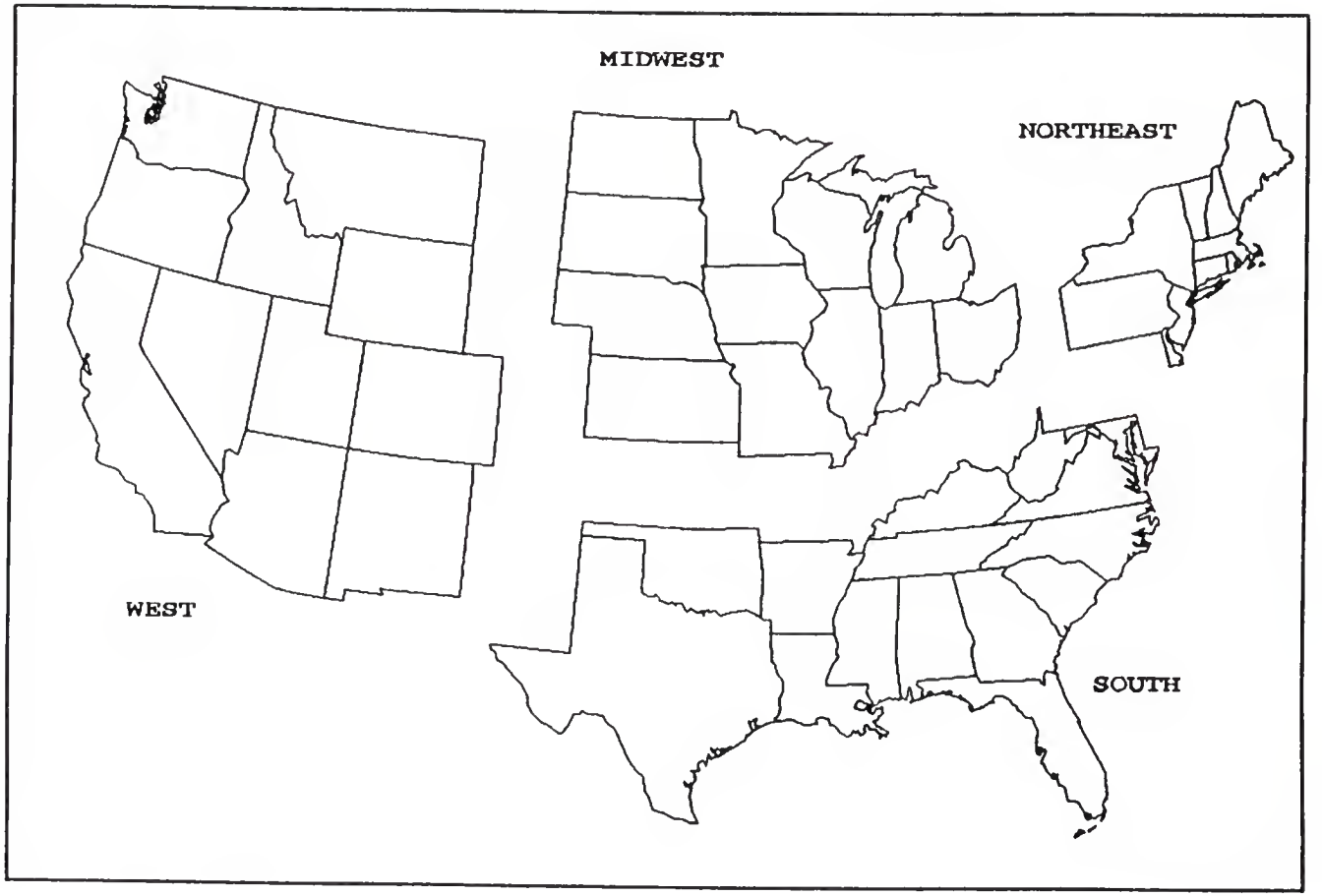

Figure 4.4. Demand regions as defined in the consumer expenditure survey.

TABLE 4.2 EXPENDITURES AND PRICES REPORTED FOR MEAT COMMODITIES BY THE BUREAU OF LABOR STATISTICS (BLS) AND THE COMMODITY CATEGORY USED IN THE DEMAND SYSTEM.

Prices Reported	Expenditures Reported	Aggregate Commodities
Turkey	Other Poultry	Other Poultry
Chicken Legs	Chicken Parts	Chicken Parts
Chicken Breast		
Whole Chicken	Whole Chickens	Whole Chickens
Beef Liver	Other Meat	
Bologna	Other Meat	Other Meat
Franks	Other Meat	
Ham, canned	Canned Ham	
Sausage	Pork Sausage	
Other Ham	Ham (excluding canned)	Pork
Pork Chop	Pork Chops	
Bacon	Bacon	
Pork Shoulder	Other Pork	
Pork Roast	Other Pork	
Porterhouse Steak	Other Steak	
T-Bone Steak	Other Steak	
Chuck Steak	Other Steak	Steak
Sirloin Steak	Sirloin Steak	
Round Steak	Round Steak	
Rib Roast	Other Roast	
Round Roast	Round Roast	Roast
Chuck Roast	Chuck Roast	
Ground Chuck	Ground Beef	Ground Beef
Ground Beef	Ground Beef	

other steak. This was done because its price was reported for only two of the demand regions. In the ground beef category only the price for ground chuck was used because the ground beef price was not reported prior to 1984. In the pork category only the prices for sausage, canned ham, pork chop, and bacon were used. Pork shoulder, pork roast and other ham were not used because their prices were not consistently reported in any of the demand regions.

The eight price indexes were calculated by using a weighted average of the prices of the individual elements of a meat category. The weights used were the individual commodities' share of consumer's expenditures on the aggregate commodity categories.

As alluded to above there was a problem with missing observations in the price series provided by the BLS. In some cases the entire price series for a commodity was not reported in one of the demand regions. This was particularly true for steak prices in the West region (see Table 4.3).

In the instances where this occurred three different approaches were used to impute the missing prices. The first approach was to use a price of a substitute commodity to represent the missing price series. This was done in the case of pork where the canned ham price was used as a proxy for the fresh ham prices. It was also done in the case of other steak where the porterhouse price was used as a proxy

TABLE 4.3 MISSING OBSERVATIONS FOR MEAT PRICES REPORTED BY THE BUREAU OF LABOR STATISTICS (BLS).

Item	Northeast	South	Midwest	West
Turkey	-	-	-	-
Chicken Legs	1986	-	1982-85	1980-86
Chicken Breast	-	-	-	-
Whole Chicken	-	-	-	-
Beef Liver	-	-	-	1983-85
Bologna	-	-	-	-
Franks	-	-	-	-
Ham, canned	-	-	-	-
Sausage	1982-86	-	-	-
Other Ham	-	-	1982-86	1982-84
Pork Chop	-	-	-	-
Bacon	-	-	-	-
Pork Shoulder	1982-86	-	1982-85	1982-86
Pork Roast	-	1980-86	1982-86	1982-85
Porterhouse Steak	-	1982, 1985	-	1982-86
T-Bone Steak	1982-86	-	-	1985, 1986
Chuck Steak	-	1986	-	1982-86
Sirloin Steak	-	-	-	1982-86
Round Steak	-	-	-	-
Rib Roast	-	-	-	-
Round Roast	-	-	-	-
Chuck Roast	-	-	-	1982-86
Ground Chuck	-	-	-	-
Ground Beef	1982, 1983	1982, 1983	1982, 1983	1982, 1983

for T-bone price in the Northeast Region. In cases where it was not possible to use a substitute price the missing price was imputed by regressing the U.S. average price on the regional prices of a commodity in the same category in order to determine the relationship between the U.S. average price and the regional prices. This relationship was then used to calculate the missing price series. This technique was applied to beef liver in the Midwest, sausage in the Northeast, and sirloin and chuck steak in the West. Finally, in the case of chicken legs where the prices were missing in both the Midwest and West the missing prices were imputed by regressing the U.S average price for whole chickens on the U.S. average price for chicken breasts and chicken legs in order to determine the relationship between the price for whole chickens, the price for chicken breasts, and the price for chicken legs. (The formulas used to impute prices are found in Appendix A Table A.1.)

There were also a few cases where a small number of observations were missing within a price series (see Table 4.3). In these cases the missing prices were imputed by using a forecast based on a simple time series regression on the price series.

By using the imputed prices the statistical properties of the estimated parameters are affected and that the resulting parameter estimates are biased. However, if the price series with missing observations are dropped then the

parameter estimates will be biased as well. This is because if the missing prices were not imputed the price index for the aggregate commodity would not account for changes in the price of a commodity which in many cases accounted for a major share of consumer's expenditures in that aggregate meat category. A more representative price index is obtained by using the information at hand to impute the missing prices than by ignoring them. Thus, a more realistic parameter estimate is obtained by using the imputed prices rather than dropping the price for which observations are missing.

Estimation Procedures

The demand model derived earlier was extended by adding dummy variables in order to account for seasonality in the monthly data. The extended demand system was estimated using a full information maximum likelihood dummy variable (FIMLDV) estimator. An iterative maximum likelihood procedure is used to allow for contemporaneous correlation in the error terms of the demand system due to the imposition of the symmetry conditions. Asymptotically no improvement results from iterating more than once, however, for finite samples iterating until convergence is achieved does lead to improvements in the estimator (Judge et al., 1985).

The FIMLDV was applied to the data in each region separately. Thus, both intercept and slope parameters are permitted to vary between regions. In terms of the

taxonomy of pooled cross-sectional estimators provided in Judge et al. (1985), the estimator used can be classified as a seemingly unrelated regression (SUR). Kmenta (1971) has indicated that in this case the regional models can be estimated separately.

The Results

The results from the estimation procedure are shown in Tables 4.4-4.7. The standard error, the t-statistic and a Durbin-Watson statistic are reported. The significance levels of the parameter estimates are mixed. The estimates of the parameters on the quantity variables with a few exceptions are significant while the effects of the seasonal variables and the quantity index are generally insignificant.

The Durbin-Watson statistic indicates that there may be a problem with autocorrelated error terms or misspecification in some of the demand equations. If there is autocorrelation then the t-statistic has no meaning. However, as pointed out in Judge et al. (1985, p. 493), the Durbin-Watson statistic is not a system wide test of autocorrelation, but only a single equation test. Although the use of the Durbin-Watson test to check for autocorrelation in systems of equations is a common practice, little is known concerning the robustness of the Durbin-Watson test when applied to a system of equations. Thus, it is possible that the Durbin-Watson indicates autocorrelation exists when in reality it does not.

TABLE 4.4 NORTHEAST DEMAND REGION RESULTS

Equation	Intercept	Quantity: Hamburger 1	Roasts 2	Steak 3	Pork 4	Other Poultry 5
Eq. 1	0.10712	0.13696	-0.01366	-0.01645	-0.04072	-0.00633
	0.01037[a]	0.00385	0.00268	0.00275	0.00350	0.00186
	10.33[b]	35.57	-5.09	-5.98	-11.62	-3.40
D.W.	0.4375					
Eq. 2	0.14033		0.08175	-0.02393	-0.02033	-0.00373
	0.00852		0.00332	0.00263	0.00329	0.00159
	16.46		24.63	-9.11	-6.18	-2.34
D.W.	1.4977					
Eq. 3	0.21690			0.12588	-0.03357	-0.00798
	0.00902			0.00396	0.00373	0.00172
	24.06			31.77	-9.00	-4.63
D.W.	1.3976					
Eq. 4	0.13136				0.16364	-0.00579
	0.01234				0.00666	0.00252
	10.65				24.57	-2.30
D.W.	1.0133					
Eq. 5	0.07975					0.03713
	0.00873					0.00215
	9.14					17.30
D.W.	2.4970					
Eq. 6	0.06435					
	0.00805					
	8.00					
D.W.	1.0270					
Eq. 7	0.09861					
	0.01274					
	7.14					
D.W.	0.6340					
Eq. 8	0.16158					
	0.00751					
	21.52					

[a]Standard error.
[b]t statistic.

TABLE 4.4--Extended

Quantity				Season Dummy		
Whole Chicken 6	Parts Chicken 7	Other Meat 8	Quantity	S1	S3	S4
-0.00934	-0.02118	-0.02928	-0.01019	0.00471	-0.00732	-0.00375
0.00211	0.00323	0.00250	0.00734	0.00333	0.00325	0.00352
-4.44	-6.56	-11.69	-1.39	1.41	-2.25	-1.07
-0.00471	-0.00251	-0.01288	0.00039	0.00188	-0.00148	0.00113
0.00182	0.00237	0.00240	0.00561	0.00263	0.00249	0.00277
-2.59	-1.06	-5.36	0.07	0.72	-0.60	0.41
-0.00866	-0.01462	-0.02066	0.00043	0.00095	-0.00285	0.00089
0.00201	0.00258	0.00271	0.00580	0.00263	0.00256	0.00286
-4.32	-5.66	-7.64	0.04	0.36	-1.11	0.31
-0.00926	-0.01028	-0.04368	-0.00901	-0.00126	0.00697	-0.00007
0.00289	0.00341	0.00327	0.00830	0.00377	0.00370	0.00415
-3.20	-3.01	-13.35	-1.09	-0.33	1.88	-0.02
-0.00237	-0.00483	-0.00609	0.01185	-0.00352	-0.00210	0.00361
0.00158	0.00216	0.00149	0.00642	0.00283	0.00283	0.00323
-1.50	-2.24	-4.09	1.85	-1.25	-0.74	1.12
0.04725	-0.00347	-0.00944	0.00327	-0.00468	-0.00093	-0.00412
0.00241	0.00234	0.00180	0.00580	0.00257	0.00260	0.00278
19.57	-1.48	-5.25	0.56	-1.83	-0.36	-1.48
	0.07191	-0.01502	0.00648	0.00273	0.00666	0.00216
	0.00433	0.00208	0.00948	0.00415	0.00419	0.00437
	16.60	-7.24	0.68	0.66	1.59	0.49
		0.13164	-0.00321	-0.00081	0.00104	0.00016
		-	0.00484	0.00224	0.00213	0.00245
		-	-0.66	-0.36	0.49	0.06

TABLE 4.5 SOUTH DEMAND REGION RESULTS

Equation	Intercept	Quantity: Hamburger 1	Roasts 2	Steak 3	Pork 4	Other Poultry 5
Eq. 1	0.12131	0.13358	-0.01556	-0.02965	-0.04121	-0.00505
	0.00729[a]	0.00342	0.00280	0.00298	0.00367	0.00132
	16.65[b]	39.03	-5.56	09.96	-11.22	-3.82
D.W.	1.1798					
Eq. 2	0.15366		0.07986	-0.01110	-0.02122	-0.00365
	0.00934		0.00460	0.00355	0.00469	0.00161
	16.45		17.37	-3.13	-4.52	-2.26
D.W.	1.6329					
Eq. 3	0.17795			0.12163	-0.03297	-0.00182
	0.01230			0.00565	0.00545	0.00205
	14.47			21.52	-6.05	-0.89
D.W.	.9388					
Eq. 4	0.11621				0.15826	-0.01247
	0.01611				0.00953	0.00268
	7.22				16.61	-4.76
D.W.	.6432					
Eq. 5	0.07056					0.03445
	0.00654					0.00146
	10.78					23.61
D.W.	2.3908					
Eq. 6	0.06339					
	0.00660					
	9.60					
D.W.	1.2515					
Eq. 7	0.13688					
	0.01141					
	11.99					
D.W.	1.2504					
Eq. 8	0.16005					
	0.00479					
	33.39					

[a]Standard error.
[b]t statistic.

TABLE 4.5--Extended

Quantity				Season Dummy		
Whole Chicken 6	Parts Chicken 7	Other Meat 8	Quantity	S1	S3	S4
-0.00667	-0.00562	-0.02983	-0.02012	0.003000	-0.00127	-0.00495
0.00193	0.00214	0.00204	0.00535	0.00213	0.00228	0.00232
-3.46	-2.62	-14.64	-3.76	1.41	-0.56	-2.13
-0.00990	-0.00312	-0.01529	-0.00645	0.00038	-0.00171	-0.00176
0.00222	0.00249	0.00217	0.00638	0.00252	0.00278	0.00277
-4.47	-1.25	-7.05	-1.03	0.15	-0.61	-0.64
-0.00310	-0.01681	-0.02618	-0.01463	-0.00245	-0.01034	-0.00804
0.00250	0.00351	0.00209	0.00937	0.00379	0.00392	0.00408
-1.24	-4.79	-12.53	-1.56	-0.65	-2.64	-1.97
-0.01267	-0.00220	-0.03526	-0.00504	0.00734	0.00874	0.00930
0.00344	0.00417	0.00279	0.01188	0.04791	0.00505	0.00507
-3.69	-0.53	-12.64	-0.42	1.53	1.73	1.84
-0.00423	-0.00268	-0.00428	0.00108	-0.00097	-0.00074	0.01053
0.00120	0.00167	0.00091	0.00496	0.00202	0.00208	0.00220
-3.52	-1.61	-4.67	0.22	-0.48	-0.35	4.78
0.05148	-0.00786	-0.00705	0.00910	-0.00070	0.00034	0.00221
0.00218	0.00189	0.00139	0.00497	0.00197	0.00208	0.00212
23.58	-4.16	-5.08	1.83	-0.35	0.16	1.04
	0.05205	-0.01375	0.03938	-0.00374	0.00548	-0.00572
	0.00383	0.00140	0.00908	0.00362	0.00371	0.00372
	13.59	-9.85	4.34	-1.03	1.48	-1.54
		0.13705	-0.00332	-0.00287	-0.00050	-0.00157
		-	0.00338	0.00134	0.00149	0.00149
		-	-0.98	-2.15	-0.34	-1.05

TABLE 4.6 MIDWEST DEMAND REGION RESULTS

Equation	Intercept	Quantity: Hamburger 1	Roasts 2	Steak 3	Pork 4	Other Poultry 5
Eq. 1	0.10896	0.15321	-0.01717	-0.02902	-0.05532	-0.00429
	0.00812[a]	0.00354	0.00249	0.00256	0.00426	0.00147
	13.41[b]	43.32	-6.89	-11.35	-12.98	-2.91
D.W.	1.0367					
Eq. 2	0.14678		0.07764	-0.01700	-0.02047	-0.00150
	0.00795		0.00352	0.00226	0.00424	0.00148
	18.47		22.09	-7.51	-4.83	-1.01
D.W.	2.0510					
Eq. 3	0.19817			0.12197	-0.03283	-0.00354
	0.00754			0.00292	0.00393	0.00136
	26.27			41.82	-8.36	-2.59
D.W.	1.1309					
Eq. 4	0.16072				0.17207	-0.00887
	0.01401				0.00961	0.00252
	11.47				17.90	-3.52
D.W.	1.0804					
Eq. 5	0.06466					0.03014
	0.01043					0.00205
	6.20					14.73
D.W.	2.3538					
Eq. 6	0.04274					
	0.00668					
	6.40					
D.W.	0.8279					
Eq. 7	0.08883					
	0.00427					
	20.81					
D.W.	1.1056					
Eq. 8	0.18914					
	0.01097					
	17.24					

[a]Standard error.
[b]t statistic.

TABLE 4.6--Extended

Quantity				Season Dummy		
Whole Chicken 6	Parts Chicken 7	Other Meat 8	Quantity	S1	S3	S4
-0.00840	-0.01176	-0.02727	-0.01050	0.00288	-0.00403	-0.00748
0.00194	0.00170	0.00365	0.00622	0.00253	0.00259	0.00279
-4.33	-6.90	-7.47	-1.69	-1.14	-1.56	-2.68
-0.00655	-0.00598	-0.00897	-0.00537	-0.00215	-0.00939	-0.00827
0.00197	0.00156	0.00366	0.00596	0.00246	0.00250	0.00269
-3.32	-3.83	-2.45	-0.90	-0.88	-3.75	03.07
-0.00564	-0.01066	-0.02328	-0.00457	-0.00207	-0.00250	-0.00698
0.00176	0.00147	0.00338	0.00574	0.00235	0.00239	0.00260
-3.20	-7.27	-6.89	-0.80	-0.88	-1.04	-2.69
-0.00841	-0.00963	-0.03653	-0.00050	0.00232	0.00489	0.00953
0.00330	0.00246	0.00653	0.01037	0.00425	0.00443	0.00468
-2.55	-3.91	-5.60	-0.05	0.55	1.10	2.03
-0.00355	-0.00242	-0.00597	0.00142	0.00089	0.00157	0.01101
0.00122	0.00079	0.00209	0.00827	0.00342	0.00342	0.00373
-2.90	-3.08	-2.86	0.17	0.26	0.46	2.95
0.04568	-0.00196	-0.01117	-0.00930	-0.00030	0.00500	0.00358
0.00223	0.00128	0.00294	0.00511	0.00210	0.00214	0.00233
20.46	-1.53	-3.80	-1.82	-0.14	2.34	1.54
	0.05444	-0.01204	-0.00194	0.00078	0.00283	0.00184
	0.00155	0.00229	0.00223	0.00130	0.00135	0.00144
	35.16	-5.27	-0.58	0.60	2.09	1.27
		0.12523	0.03075	-0.00235	0.00164	-0.00323
		-	0.00835	0.00341	0.00359	0.00385
		-	3.68	-0.69	0.46	-0.84

TABLE 4.7 WEST DEMAND REGION RESULTS

Equation	Intercept	Quantity				
		Hamburger 1	Roasts 2	Steak 3	Pork 4	Other Poultry 5
Eq. 1	0.13559	0.13511	-0.00189	-0.03136	-0.04208	-0.00648
	0.00917[a]	0.00441	0.00267	0.00297	0.00379	0.00181
	14.79[b]	30.62	-0.71	-10.55	-11.10	-3.57
D.W.	1.1546					
Eq. 2	0.14481		0.04475	-0.00681	-0.01752	-0.00312
	0.01426		0.00498	0.00339	0.00433	0.00263
	10.15		9.00	-2.01	-4.05	-1.19
D.W.	1.3972					
Eq. 3	0.23876			0.13590	-0.04588	-0.01012
	0.01216			0.00485	0.00446	0.00244
	19.64			28.01	-10.30	-4.15
D.W.	1.1333					
Eq. 4	0.12427				0.16471	-0.00935
	0.01460				0.00787	0.00299
	8.51				20.93	-3.13
D.W.	1.2924					
Eq. 5	0.02821					0.03948
	0.01125					0.00272
	2.51					14.51
D.W.	2.2659					
Eq. 6	0.07232					
	0.00568					
	12.73					
D.W.	1.111					
Eq. 7	0.11137					
	0.00904					
	12.31					
D.W.	0.8655					
Eq. 8	0.14468					
	0.01149					
	12.60					

[a]Standard error.
[b]t statistic.

TABLE 4.7--Extended

Quantity				Season Dummy		
Whole Chicken 6	Parts Chicken 7	Other Meat 8	Quantity	S1	S3	S4
-0.00755	-0.01238	-0.03337	-0.00377	-0.00068	-0.00398	-0.00572
0.00181	0.00220	0.00341	0.00697	0.00297	0.00286	0.00289
-4.16	-5.63	-9.80	-0.54	-0.23	-1.39	-1.98
-0.00102	-0.00486	-0.00953	0.01690	0.00401	-0.00118	0.00059
0.00172	0.00267	0.00342	0.01130	0.00490	0.00456	0.00475
-0.59	-1.82	-2.79	1.50	0.82	-0.26	0.12
-0.00683	-0.01309	-0.02181	0.00360	-0.00791	-0.00850	-0.00695
0.00194	0.00286	0.00367	0.00962	0.00413	0.00388	0.00402
-3.53	-4.57	-5.94	0.37	-1.92	-2.19	-1.73
-0.00950	-0.01404	-0.02633	-0.00321	0.00249	0.00752	0.01015
0.00237	0.00326	0.00486	0.01137	0.00488	0.00466	0.00477
-4.01	-4.31	-5.42	-0.28	0.51	1.61	2.13
0.00006	-0.00153	-0.00894	-0.03443	0.00866	0.00300	0.00891
0.00116	0.00179	0.00248	0.00920	0.00397	0.00373	0.00390
0.05	-0.85	-3.60	-3.74	2.18	0.81	2.28
0.04324	-0.00840	-0.01001	0.01003	-0.00037	0.00031	-0.00107
0.00150	0.00145	0.00213	0.00448	0.00190	0.00179	0.00184
28.74	-5.79	-4.70	2.24	-0.19	0.18	-0.58
	0.05794	-0.00365	0.01271	-0.00134	0.00405	0.00034
	0.00268	0.00272	0.00719	0.00308	0.00290	0.00301
	21.61	-1.34	1.77	09.44	1.40	0.11
		0.11364	-0.00183	-0.00486	-0.00123	-0.00625
		-	0.00896	0.00385	0.00368	0.00379
		-	-0.20	-1.26	-0.33	-1.65

The appropriate test for autocorrelation would be one which included the error terms from all the equations. In a system of equations with first order autoregressive disturbances, the disturbances in all equations in time period t are related to the previous period's disturbances by

$$e_t = Re_{t-1} + v_t$$

where e_t is a (M x 1) vector of disturbances in period t, e_{t-1} is a (M x 1) vector of disturbances lagged on time period, R is a (M x M) matrix of ρ_{ij}'s and v_t is a (M x 1) vector of random disturbances with $E[v_{it}]=0$ and $E[v_{it}v_{js}]=\sigma_{ij}$ for t=s, but zero otherwise. R is estimated by regressing e_{it} on $(e_{1t-1}, e_{2t-1}, \ldots, e_{Mt-1})$.

Judge et al. (1985, p. 494) propose a likelihood ratio test for first order autocorrelation in systems of equations. Let E represent the ((T-1) x M) matrix obtained from dropping the first row from the residual matrix of the estimated system, E_{-1} be the ((T-1) x M) obtained from deleting the last row from the residual matrix,

$$\Sigma = (T-1)^{-1}(E - E_{-1}R)'(E - E_{-1}R)$$

and $\Sigma_0 = (T-1)^{-1}E'E$. Then under the null hypothesis R=0

$$u = (T-1)(\ln|\Sigma_0| - \ln|\Sigma|)$$

converges in distribution to a $\chi(m^2)$ random variable.

The likelihood ratio test was applied to the Midwest region. The value of the test statistic was 1.932. Consequently, the null hypothesis that there is no autocorrelation could not be rejected. Given the results obtained for the Midwest the test was not applied to any of the other demand regions.

The AIDS model has as one of its characteristics that the parameter on the own-quantity variable is positive. Thus, it is not possible to determine whether the demand curves are downward sloping simply by looking at these parameters. In order to determine this it is necessary to evaluate the partial derivative of the demand equations with respect to their own quantity. Given this it is easier to determine whether the demand curves are downward sloping by looking at the demand flexibilities.

Flexibilities are calculated at the means of the data for each of the four demand regions and reported in Tables 4.8-4.11. The formula used to calculate the flexibilities,

$$e_{ij} = -\delta_{ij} + \gamma_{ij}/w_i - \beta_i/w_i(w_i + \Sigma_k w_k \ln q_k(e_{kj} + \delta_{kj})$$

where δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ for $i = j$; $\delta_{ij} = 0$ otherwise, was adapted from Green and Alston (1990, p. 443).

TABLE 4.8 FLEXIBILITIES FOR MEATS IN THE NORTHEAST REGION.

Description	GB	Roasts	Steak	Pork	Other Poultry	Chicken Whole	Chicken Parts	Other Meat
Ground Beef	-0.151	-0.089	-0.110	-0.275	-0.040	-0.062	-0.140	-0.201
Roasts	-0.148	-0.109	-0.260	-0.220	-0.041	-0.051	-0.027	-0.139
Steaks	-0.104	-0.152	-0.202	-0.212	-0.051	-0.055	-0.092	-0.130
Pork	-0.193	-0.094	-0.156	-0.270	-0.027	-0.044	-0.051	-0.209
Other Poultry	-0.109	-0.088	-0.186	-0.064	0.018	-0.050	-0.099	-0.080
Chicken, Whole	-0.165	-0.087	-0.158	-0.157	-0.044	-0.102	-0.059	-0.162
Chicken, Parts	-0.203	-0.023	-0.142	-0.157	-0.049	-0.032	-0.261	-0.135
Other Meat	-0.137	-0.060	-0.096	-0.205	-0.028	-0.044	-0.070	-0.250

TABLE 4.9 FLEXIBILITIES FOR MEATS IN THE SOUTH REGION.

Description	GB	Roasts	Steak	Pork	Other Meat	Chicken Whole	Chicken Parts	Other Poultry
Ground Beef	-0.218	-0.085	-0.155	-0.191	-0.149	-0.031	-0.024	-0.029
Roasts	-0.151	-0.150	-0.110	-0.200	-0.150	-0.101	-0.028	-0.039
Steaks	-0.173	-0.069	-0.198	-0.179	-0.153	-0.014	-0.103	-0.012
Pork	-0.161	-0.085	-0.130	-0.356	-0.138	-0.050	-0.007	-0.051
Other Meat	-0.145	-0.101	-0.053	-0.362	-0.123	-0.118	-0.076	-0.053
Chicken, Whole	-0.148	-0.174	-0.072	-0.276	-0.149	-0.126	-0.146	-0.073
Chicken, Parts	-0.177	-0.054	-0.273	-0.215	-0.265	-0.132	-0.373	-0.035
Other Poultry	-0.189	-0.099	-0.168	-0.221	-0.062	-0.044	-0.088	-0.028

TABLE 4.10 FLEXIBILITIES FOR MEATS IN THE MIDWEST REGION.

Description	GB	Roasts	Steak	Pork	Other Poultry	Chicken Whole	Chicken Parts	Other Meat
Ground Beef	-0.211	-0.092	-0.156	-0.309	-0.022	-0.047	-0.063	-0.160
Roasts	-0.209	-0.127	-0.196	-0.252	-0.017	-0.177	-0.069	-0.120
Steaks	-0.218	-0.123	-0.123	-0.248	-0.025	-0.042	-0.078	-0.0178
Pork	-0.218	-0.080	-0.129	-0.325	-0.035	-0.033	-0.038	-0.144
Other Poultry	-0.122	-0.045	-0.107	-0.261	-0.060	-0.109	-0.074	-0.172
Chicken, Whole	-0.216	-0.136	-0.127	-0.232	-0.070	-0.099	-0.044	-0.280
Chicken, Parts	-0.204	-0.100	-0.180	-0.171	-0.040	-0.034	-0.097	-0.210
Other Meat	-0.083	-0.035	-0.091	-0.112	-0.026	-0.043	-0.049	-0.264

TABLE 4.11 FLEXIBILITIES FOR MEATS IN THE WEST REGION.

Description	GB	Roasts	Steak	Pork	Other Poultry	Chicken Whole	Chicken Parts	Other Meat
Ground Beef	-0.261	-0.011	-0.175	-0.239	-0.036	-0.042	-0.069	-0.188
Roasts	0.023	-0.467	-0.060	-0.138	-0.034	-0.044	-0.045	-0.074
Steaks	-0.185	-0.040	-0.173	-0.271	-0.061	-0.041	-0.078	-0.128
Pork	-0.181	-0.075	-0.196	-0.308	-0.040	-0.041	-0.060	-0.114
Other Poultry	-0.347	-0.112	-0.331	-0.513	-0.049	-0.032	-0.087	-0.375
Chicken, Whole	-0.104	-0.011	-0.115	-0.212	0.004	-0.136	-0.155	-0.161
Chicken, Parts	-0.121	-0.055	-0.150	-0.123	-0.018	-0.100	-0.255	-0.016
Other Meat	-0.204	-0.058	-0.133	-0.162	-0.054	-0.061	-0.023	-0.294

All the own-quantity flexibilities are negative which is consistent with theoretical expectations. The exception is the own-flexibility for other poultry in the northeast region. The positive sign for the own-flexibility of other poultry while disturbing is not totally inexplicable considering the large amount of seasonal variation in the level of other poultry consumption. There is also a large amount of seasonal variation in the price of other poultry which coincides with the variation in consumption levels. Increased consumption of other poultry and the increased price of poultry during the fourth quarter is probably due to the holidays. This is a period when the demand for turkey increases because it is traditional for Americans to serve roast turkey for dinner on Thanksgiving and Christmas. This, combined with the decline in prices and the low level of consumption of turkey during the other three quarters due to the demand for turkey shifting inward, provides a plausible explanation for the positive sign on the own flexibility for other poultry in the Northeast.

A comparison of the own-quantity flexibilities to the cross-flexibilities indicates that an increase in the quantity of each meat has a strong negative effect on the prices of the other meat products. This supports the need to incorporate interrelated demand systems into the programming model.

Elasticities and flexibilities from other demand studies are reported in Table 4.12. Of the four studies only Dahlgran (1987) estimated flexibilities. Unfortunately, Dalhgran's model only includes a single aggregate beef variable. Thus, it is not readily possible to make a comparison between the results from his study to the results obtained here. Dahlgran's results indicate that the price for beef is flexible which is opposite of the results reported in this study. It is possible given the strong cross effects between the meat products that the disaggregate products could be inflexible and still have an aggregate flexibility that is flexible.

The other three studies report only price elasticities. There is little consistency between the studies in reported elasticities for ground beef, roast and steak. While Eales and Unnevehr (1988), and Capps and Havlicek (1984) report that the demand for ground beef is elastic, Heien and Pompelli (1988) report that demand for ground beef is inelastic. Similarly, Eales and Unnevehr (1988) and Heien and Pompelli (1988) report strong cross effects while Capps and Havlicek (1984) report relatively weak cross effects.

It is difficult to evaluate the results obtained here based on the results obtained in the other four demand studies. This is because all of the studies differ as to the type of data used (cross-section, annual time series or

TABLE 4.12. ELASTICITIES AND FLEXIBILITIES FOR BEEF REPORTED IN OTHER DEMAND STUDIES.

Researcher	Model	Equations	Elasticities		
Eales and Unnevehr	AIDS		Gb	Table Cuts	
		Gb	-2.593	1.593	
		Table cuts	0.384	-.684	
Capps and Havlicek	S_1-Branch System		Gb	Roast	Steak
		Gb	-1.52	.06	.07
		Roast	0.04	-1.83	.09
		Steak	0.04	.07	-1.75
Heien and Pompelli	AIDS		Gb	Roast	Steak
		Gb	-.85	.05	.21
		Roast	.13	-1.11	-.39
		Steak	-.24	-.17	-.73
Dahlgran	Inverse Rotterdam		Beef[a]	Pork	Chicken
		Beef	-1.75	-4.39	-.160
		Pork	-.81	-1.96	-.267
		Chicken	-.63	-.58	-1.72

[a]Flexibilities

pooled monthly cross-section and time series), the time period spanned, the method used to obtain data (survey or disappearances), preference structure assumed and functional form used. In the demand systems estimated in this dissertation the data set used pooled cross-section survey data on monthly household expenditures on meat from 1982-1986. Eales and Unnevehr (1988) used annual disappearance data from 1965-1985 in their study, Dahlgran (1987) used annual disappearance data from 1950-1985, while Capps and Havlicek (1985) and Heien and Pompelli (1988) used cross-sectional household expenditure survey data from 1977. All the studies except this one and Eales and Unnevehr assumed that preferences were separable by species.

All of these factors will cause the estimated parameters obtained from the studies to vary. In particular, one would expect the parameters estimated from data obtained after the change in the structure of demand for meat occurred. Monthly data contains more variation than annual data. Thus, the use of monthly data may cause there to be an appearance of greater substitution among the individual meat commodities than actually occurs. Which of the two, monthly or annual, is more representative of consumer response to changes in prices is open to debate. Finally, if preferences for meat are not separable by species than studies which assume that preferences are

separable by species will have different parameter estimates than those which do not make this assumption.

Adjustments Made to Demand Equations

Before the estimated inverse demand systems can be used in the programming model several steps need to be taken. The first step is to aggregate the household demand system up to the market level. The second step is to evaluate each demand system's Jacobian matrix to determine the range of quantities over which it satisfies the negative definiteness, restriction.

Given that the estimated demand system permits perfect aggregation the household level demand system can be transformed into a market level demand system by substituting $q=Y/P$ and $x=M/P$ (where q represents household consumption, Y is equal to market level consumption, P represents the total number of households in the market, x is equal to household level of expenditures, and M is equal to the level of total expenditures in the market) into the household level demand system and simplifying.

It is necessary to evaluate the Jacobian matrix of the market level demand system for two reasons. The first reason is that while the symmetry requirement has been imposed in estimation the negative definiteness of the system's Jacobian has not been imposed. Secondly, flexible demand systems such as the AIDS model only satisfy the demand theory properties locally and not globally. At first

this was believed to imply that the demand system would satisfy the conditions at each of the points in the data set. However, Caves and Christensen (1980) have pointed out that in actual practice this has never been true. Evaluations of the global properties of such flexible functional forms such as the Leontief and Translog models have indicated that there is a very small range of values over which flexible systems satisfy the properties derived from economic theory.

It is preferable that the demand systems satisfy the integrability conditions globally. Given the properties of flexible forms, however, it is unreasonable to expect them to meet this condition. It does seem reasonable to expect that they satisfy the integrability conditions over minimum and maximum quantities of hamburger, steak and roasts observed in the data set.

Before evaluating the Jacobian matrixes of the market level demand systems it was necessary to set the levels of the exogenous variables (pork, other meat, poultry, expenditure and the quantity index) at their means.[1] When evaluated at the means of the data only three of the four Jacobians were negative definite. When the Jacobians were evaluated at each of the observations in the data set the

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[1]By holding the quantity index ln(Q) constant the demand equations only approximate the compensated demand system. For information on how to obtain the empirical compensated system see Appendix D.

results were mixed. For the Midwest and the Northeast negative definiteness was rejected at a majority of the data points. For the West and South the results were better with negative definiteness holding at 67-83% of the data points. These results indicate that it is necessary to determine a range of quantities for which the negative definiteness property holds in order to use the demand systems for simulation purposes.

It was decided to adjust the own-quantity parameters by adding k to them in order to ensure that they satisfy the negative definiteness criteria. This is common practice in the engineering literature to adjust the diagonal elements of a system of equations in order to ensure that their Jacobians are negative definite. It was also decided that it would be best to set the exogenous variables at their minimum values when using them in the programming model. This was done to ensure the demand systems would be negative definite over the greatest range possible. This is an unorthodox procedure in that typically variables are set at their means of the data. The value used for k was 0.005 in all regions except for the West where k=.0025 was used. These two adjustments enabled the demand systems in each region to be negative definite over the range of values shown in Table 4.13.

Finally, the demand equations were adjusted by multiplying the original intercept term by the values shown in

TABLE 4.13 LOWER AND UPPER BOUNDS ON BEEF VARIABLES, HOUSEHOLD LEVEL.

Area	Bounds	Hamburger	Roast	Steak
		(lbs/month)		
Northeast	Upper	7.2	3.3	4.0
	Lower	2.1	1.0	0.8
South	Upper	8.1	4.0	7.0
	Lower	2.4	0.4	1.4
Midwest	Upper	7.7	2.75	3.5
	Lower	2.8	1.2	1.475
West	Upper	7.0	2.75	4.0
	Lower	2.3	0.4	1.3

TABLE 4.14 ADJUSTMENT MADE TO INTERCEPT OF DEMAND EQUATIONS.

	Region			
Equation	North-east	South	Mid-west	West
Hamburger	95	87	90	92
Roast	94	78	80	77
Steak	102	87	85	88

Table 4.14. This was done to reorient the demand system in commodity space so that it forecast prices in the same range as found in the data used to estimate the demand system. It was necessary to do this because all the variables in the demand equations except the beef variables were held constant at their minimum observed value. Consequently, the forecasted prices generated using the demand system without the adjustments made to the intercepts were higher than the observed prices.

After all the adjustments were made the parameters on the demand system to be used in the programming model are shown in Table 4.15. The intercepts have negative signs. This is because of the negative impact the other meat products have on the price of the beef products.

TABLE 4.15 PARAMETER VALUES FOR MARKET LEVEL DEMAND EQUATIONS USED IN THE PROGRAMMING MODEL.

	Variables			
Equation	Inter-cept	Ham-burger	Roast	Steak
Northeast				
Hamburger	-1.767	0.1395	-0.0137	-0.0164
Roast	-0.641	-	0.0843	-0.0239
Steak	-1.265	-	-	0.1284
South				
Hamburger	-1.463	0.1361	-0.0156	-0.0297
Roast	-0.825	-	0.0824	-0.0111
Steak	-1.272	-	-	0.1241
Midwest				
Hamburger	-1.806	0.1557	-0.0172	-0.0290
Roast	-0.653	-	0.0801	-0.0170
Steak	-1.175	-	-	0.1245
West				
Hamburger	-1.642	0.1352	-0.0019	-0.0314
Roast	-0.501	-	0.0449	-0.0068
Steak	-0.147	-	-	0.136

CHAPTER 5
DESCRIPTION OF ACTIVITY ANALYSIS MODEL OF BEEF PRODUCTION SYSTEM

The purpose of this chapter is to describe the activity analysis model used to represent the beef production system. In the model the U.S. is divided into five supply regions: the Southeast, the Midwest, the Southwest, the Plains and the West. The supply regions as shown in Figure 5.1 are consistent with the supply regions reported in the Census of Agriculture. All five stages of production: cow-calf, growing, finishing, slaughtering and processing, and distributing are represented in the model. The flow of products through the beef production system as represented in the model is shown in Figure 5.2. Production activities at each stage of production and the interregional flow of products from one stage of production to another are depicted by sets of activity constraints or equations.

The two production activities represented at the cow-calf stage are the production of weaned calves and the production of culls. After weaning the calves are transferred to either the stocker (growing) stage or to the finishing stage, while the culled breeding stock is transferred directly to the slaughtering stage.

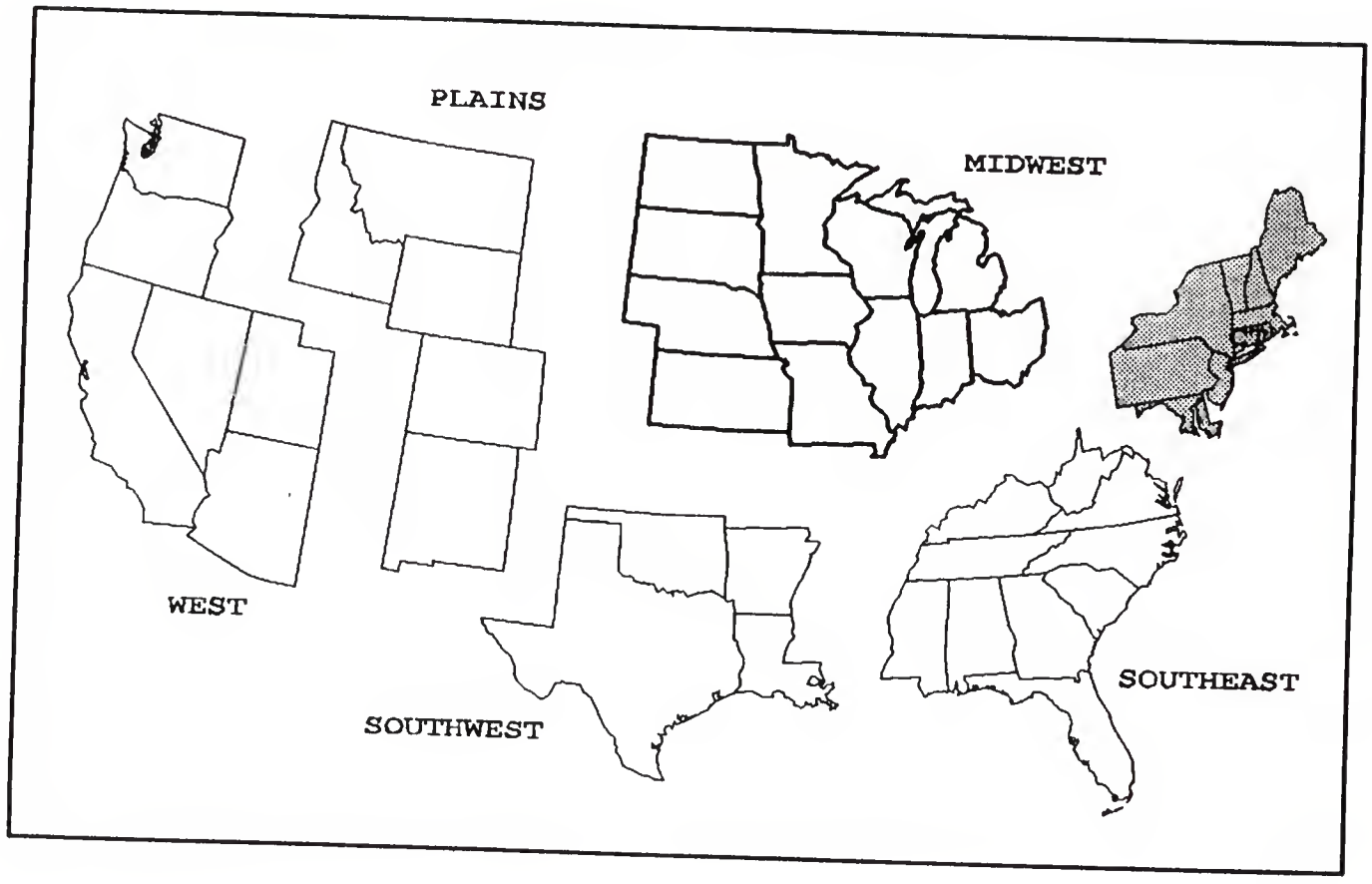

Figure 5.1. Supply regions as defined in model.

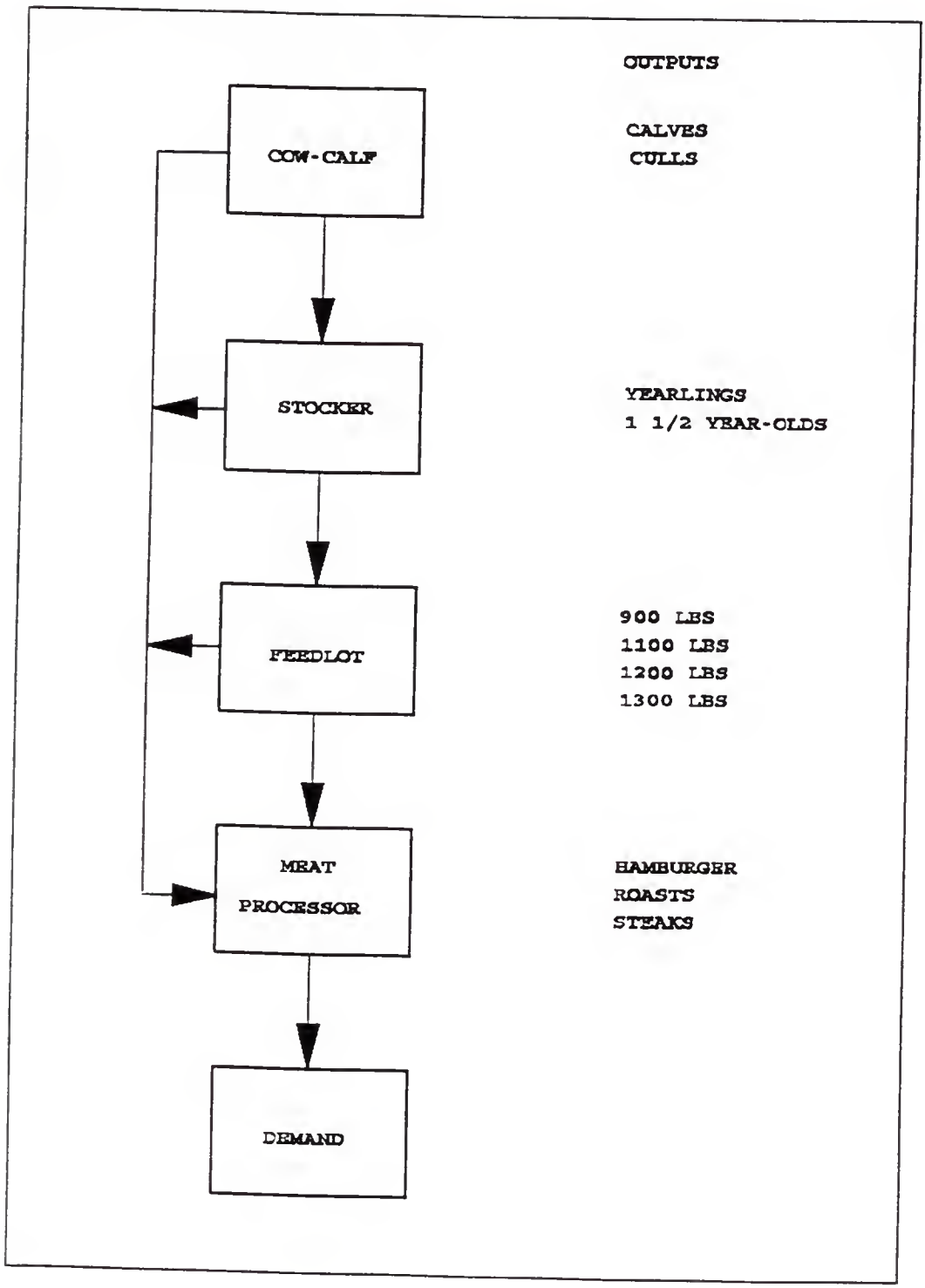

Figure 5.2. Activity analysis model of beef production system.

Both the supply of calves and the supply of culls are determined by multiplying the number of cows in the breeding herd by the calving and culling rates shown in Table 5.1. The calving rate represents the average rate at which one cow produces a stocker or feeder calf over all the herds in a supply region. The culling rate used is actually the replacement rate reported in the cow-calf production budgets. Thus it is being assumed that the cow herd was neither contracting or expanding in size during the time period over which the replacement rate was calculated. For if the breeding herd was decreasing in size during this time period then by using the replacement rate as a proxy for the culling rate the model would be underestimating the number of culls produced while if the size of the breeding herd was expanding then using the replacement rate as a proxy for the culling rate would cause the supply of beef culls to be overestimated.

Reliable production budgets at the cow-calf stage were not available. As a consequence the size of the breeding herd is fixed at a predetermined level rather than letting it be determined by the model. The size of the breeding herd in each region is fixed at a level which represents the average size of the breeding herd in each supply region over the five year period 1982-1986 (see Table 5.1 and Appendix B Tables B.1 and B.2).

TABLE 5.1 SIZE OF BREEDING HERD AND CALVING AND CULLING RATES

Region	Head Breeding Stock	Calving Rate	Culling Rate
	-millions-		
Southeast	7.0852	0.59	0.10
Midwest	11.1732	0.61	0.14
Southwest	9.0888	0.63	0.12
West	2.0547	0.57	0.17
Plains	4.9464	0.62	0.16

Source: USDA, 1989.

TABLE 5.2 COST OF PRODUCTION OF COW-CALF STAGE.

Region	Culls	Calves
	$/head	
Southeast	346.937	256.856
Midwest	417.683	303.598
Southwest	384.120	247.026
West	414.094	243.356
Plains	409.851	281.134

In the absence of production budgets for cow-calf activities the market prices for calves and beef culls are used to represent the costs of production activities at the cow-calf stage (see Table 5.2). Thus, it is assumed that the price received is equal to the average cost of production of weaned calves and culls. The prices were obtained by multiplying the price per lb. for calves and culls ass reported by USDA times their average weight of calves or culls.

In the stocker stage weaned calves coming from the cow-calf stage are used to produce yearlings and 1 1/2 year olds. The yearlings are produced by placing incoming calves on pasture for a period of six months while the 1 1/2 year olds are produced by keeping the incoming calves on pasture for a period of one year. The yearlings and 1 1/2 year olds produced are transferred either to the finishing stage or to the slaughtering-processing stage.

The costs of production at the stocker stage are shown in Table 5.3. They are derived from production budgets for stocker operations in each of the supply regions (see Appendix B Table B.3). The differences in the costs of production for yearlings and 1 1/2 year olds reflect the differences in the length of time they are stockered. The costs shown represent all costs incurred in stockering activities, such as land and labor, except the cost of the weaned calf on a per head basis.

TABLE 5.3 COST OF PRODUCTION ACTIVITIES AT THE STOCKER STAGE

Region	Yearling	1 1/2 Years Old
	$/head	
Southeast	91.129	211.953
Midwest	93.701	223.279
Southwest	90.814	215.691
West	110.172	274.496
Plains	104.953	249.682

At the finishing stage weaned calves coming from the cow-calf stage and yearlings and 1 1/2 year olds coming from the stockering stage are placed on the feedlot where they are transformed into fed cattle. The fed cattle are then transferred from the feedlot to the slaughtering-processing stage. There are six production activities and four alternative finishing weights represented in the model. Each of the three types of feeder cattle can be raised to two different weights representing a long and short feeding program. Weaned calves coming from the cow-calf stage are finished at either 900 or 1,100 lbs., while yearlings coming from the stockering stage are finished at 900 or 1,200 lbs., and 1 1/2 year olds coming from the stockering stage are finished at 1,100 or 1,300 lbs.

The average costs of each of the six production activities are shown in Table 5.4. The costs of production are calculated from production budgets for each of the feeding activities (see Appendix B Table B.4). The costs include all costs incurred at the finishing stage except the cost of the feeder cattle. The cost of corn along with fixed and variable costs is explicitly represented in the production budgets. Thus, it is possible to analyze the impact of changes in the cost of feed on the cost of the production activities.

At the slaughter-processing stage live cattle are rendered into hamburger, roasts, and steaks. The type of

TABLE 5.4 COST OF FINISHING UP TO FINAL WEIGHT.

Region	Calf		Yearling		1 1/2 Years	
	900 lbs	1,100 lbs	1,200 lbs	900 lbs	1,300 lbs	1,100 lbs
	$/head					
Southeast	276.352	420.049	438.282	199.011	448.765	251.067
Midwest	258.430	392.815	412.881	187.534	422.675	237.169
Southwest	251.582	384.331	401.117	182.138	411.082	238.073
West	290.800	443.034	451.106	205.754	479.130	267.710
Plains	213.875	377.039	396.720	180.332	417.784	233.126

cattle coming into the slaughter-processing stage are yearlings and 1 1/2 year olds from the stockering stage, 900 lb., 1,100 lb., 1,200 lb., 1,300 lb. fed cattle from the finishing stage, and culls from cow-calf stage and the dairy herd. The supply of dairy culls is fixed exogenously. Both the number of dairy culls available in each region and their cost to the slaughtering plant are shown in Table 5.5. The live cattle coming into this stage are slaughtered and fabricated into primal cuts (roasts, steaks, lean trim, medium trim, and fat and bone). The different cuts and their weights by live cattle type are shown in Table 5.6. Primal cuts are transferred either to a sales activity or to a hamburger processing activity. Only roasts and steaks are permitted to be transferred directly to the sales activity. All of the primal cuts except fat and bone may be used in hamburger production. The production of hamburger production is also constrained by the requirement that hamburger can consist of no more than 27% fat. Steaks and roasts contain 20% fat, lean trim contains 15% fat, medium trim contains 50% trim, and fat and bone is 100%. (See Appendix B Tables B.5 and B.6 for the derivation of the weight of each cut.)

The costs of production at the slaughtering and fabricating step are shown in Table 5.7. These costs represent the average cost per head in a meatpacking plant being utilized at full capacity. The differences in the

TABLE 5.5 SUPPLY OF DAIRY CULLS AND THEIR COST BY REGION

Region	Number	Cost
		-$/head-
Southeast	331,200	346.937
Midwest	2,332,600	417.683
Southwest	200,300	384.120
West	608,400	405.194
Plains	122,900	418.854

TABLE 5.6. WEIGHT OF FABRICATED CUTS BY REGION.

Region	Cut	900	1,100	1,200	1,300	Year-lings	1 1/2 Years	Culls
		cwt						
Southeast	Roast	1.203	1.520	1.686	1.856	0.704	0.968	0.398
	Steak	1.452	1.835	2.035	2.241	0.846	1.163	0.477
	Lean trim	0.535	0.676	0.750	0.826	0.741	1.019	2.319
	Medium trim	0.588	0.743	0.824	0.908	0.404	0.556	0.131
	Fat and bone	1.521	1.922	2.132	2.347	0.674	0.927	1.050
Midwest	Roast	1.246	1.565	1.731	1.902	0.739	1.004	0.429
	Steak	1.503	1.889	2.090	2.296	0.888	1.206	0.513
	Lean trim	0.554	0.696	0.770	0.846	0.778	1.057	2.496
	Medium trim	0.609	0.765	0.846	0.930	0.424	0.577	0.141
	Fat and bone	1.575	1.978	2.189	2.405	0.707	0.961	1.130
Southwest	Roast	1.145	1.461	1.619	1.795	0.658	0.920	0.409
	Steak	1.382	1.763	1.954	2.166	0.790	1.105	0.490
	Lean trim	0.509	0.650	0.720	0.799	0.692	0.968	2.385
	Medium trim	0.560	0.714	0.791	0.878	0.378	0.528	0.135
	Fat and bone	1.448	1.847	2.046	2.269	0.629	0.880	1.080
West	Roast	1.179	1.495	1.633	1.831	0.685	0.948	0.435
	Steak	1.423	1.805	1.971	2.210	0.822	1.139	0.522
	Lean trim	0.524	0.665	0.726	0.814	0.721	0.998	2.536
	Medium trim	0.576	0.731	0.798	0.895	0.393	0.544	0.144
	Fat and bone	1.490	1.891	2.064	2.314	0.655	0.907	1.148
Plains	Roast	1.199	1.516	1.682	1.852	0.701	0.965	0.440
	Steak	1.447	1.830	2.030	2.235	0.842	1.159	0.528
	Lean trim	0.533	0.675	0.748	0.824	0.738	1.016	2.565
	Medium trim	0.586	0.741	0.822	0.906	0.402	0.554	0.145
	Fat and bone	1.516	1.917	2.126	2.341	0.671	01.923	1.162

TABLE 5.7 AVERAGE COST OF SLAUGHTERING AND PROCESSING HAMBURGER BY REGION.

Region	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Live Animal			($/head)		
Southeast	88.585	-	-	-	-
Midwest	77.399	68.938	65.001	62.593	60.650
Southwest	77.399	68.938	65.001	62.593	60.650
West	88.585	-	-	-	-
Plains	77.399	68.938	62.539	-	-
Hamburger			($/cwt)		
Southeast	3.629	-	-	-	-
Midwest	3.060	2.725	2.569	2.474	2.398
Southwest	3.288	2.928	2.761	2.659	2.576
West	3.661	-	-	-	-
Plains	3.143	2.799	2.542	-	-

Source: Nelson, 1989.

average cost of slaughtering between the meatpacking plants are due to the different capacities of the meatpacking plants used. The cost of slaughtering decreases as the capacity of the meatpacking plant increases. This reflects the fact that the meatpacking industry is characterized by increasing returns to size. The capacity of each type of meatpacking plant located in a supply region and the total capacity in each region are shown in Table 5.8. The cost of making hamburger is estimated to be 23% of the cost of slaughtering and fabricating. (See Appendix B Table B.7 for further details.)

Transfer activities in the model move the live cattle up through the vertical sector and between the supply regions. Transportation costs, shrinkage due to death loss, interregional weight adjustments, and a processor to retail marketing margin are all accounted for in the transfer activities.

The cost of transporting live animals from one supply region to another are shown in Tables 5.9 and 5.10 and the costs of transporting hamburger, roasts and steaks from supply to demand regions are shown in Table 5.11. The costs of transporting live animals between supply regions were estimated by Kennedy and updated by Disney. They are based on distance traveled and the weight of the animal being transported (see Appendix B Table B.8).

TABLE 5.8 SIZE AND NUMBER OF MEATPACKING PLANTS.

Region	125,000	250,000	500,000	750,000	1,000,000	1,300,000	Total
Southeast	14	-	-	-	-	-	1,750,000
Midwest	-	5	14	6	2	3	18,650,000
Southwest	-	7	1	2	1	1	6,050,000
Plains	-	1	6	-	1	-	4,250,000
West	18	-	-	-	-	-	2,250,000
Total	32	13	21	8	4	4	30,289,000

Source: Faminow and Sarhan, 1983.

TABLE 5.9 TRANSPORTATION COSTS FOR CULLS, CALVES, AND STOCKERED CATTLE.

Origin/ Destination Region	Culls	Calves	Year-lings	1 1/2 Years
		$/hd		
Southeast				
Southeast	2.541	1.257	1.882	2.492
Midwest	34.833	17.237	25.796	34.156
Southwest	31.445	15.561	23.287	30.834
Plains	43.197	21.376	31.990	42.358
Midwest				
Southeast	37.500	18.511	27.070	35.430
Midwest	4.103	2.026	2.962	3.877
Southwest	27.014	13.335	19.500	25.523
Plains	14.932	7.371	10.779	14.107
Southwest				
Southeast	32.343	14.015	21.742	29.289
Midwest	28.423	12.317	19.107	25.739
Southwest	4.792	2.076	3.221	4.339
West	46.391	20.103	31.185	42.010
Plains	20.255	8.777	13.616	18.342
West				
Southwest	52.109	22.597	34.303	45.738
West	6.253	2.712	4.116	5.489
Plains	44.466	19.283	29.272	39.030
Plains				
Southeast	47.788	21.228	31.842	42.210
Midwest	15.344	6.816	10.224	13.553
Southwest	21.786	9.678	14.516	19.243
West	38.535	17.118	25.677	34.037
Plains	5.856	2.601	3.902	5.173

TABLE 5.10 TRANSPORTATION COSTS FOR FED BEEF BY REGION.

Origin/ Destination Region	900	1,100	1,200	1,300
	$/head			
Southeast				
Southeast	2.608	3.189	3.479	3.769
Midwest	35.748	43.710	47.691	51.672
Southwest	32.271	39.459	43.053	46.646
Plains	44.332	54.206	59.143	64.080
Midwest				
Southeast	37.022	44.984	48.965	52.946
Midwest	4.051	4.922	5.358	5.793
Southwest	26.670	32.405	35.273	38.140
Plains	14.741	17.912	19.497	21.082
Southwest				
Southeast	30.726	37.914	41.328	45.101
Midwest	27.002	33.318	36.318	39.634
Southwest	4.552	5.617	6.123	6.682
West	44.072	54.381	59.278	64.690
Plains	19,243	23,744	25,882	28,245
West				
Southwest	47.916	58.806	63.162	69.696
West	5.750	7.057	7.579	8.364
Plains	40.888	50.181	53.898	59.474
Plains				
Southeast	44.184	54.058	58.995	63.932
Midwest	14.187	17.357	18.942	20.527
Southwest	20.143	24.644	26.895	29.145
West	35.629	43.591	47.572	51.553
Plains	5.415	6.625	7.230	7.835

TABLE 5.11 TRANSPORT COST BOXED BEEF FROM SUPPLY TO DEMAND REGIONS.

Destination/ Origin Region	Roast	Steak	Ham-burger
		$/cwt	
Northeast			
Southeast	3.017	3.017	3.017
Midwest	3.547	3.547	3.547
Southwest	4.311	4.311	4.311
Plains	4.098	4.098	4.098
South			
Southeast	1.733	1.733	1.733
Midwest	2.835	2.835	2.835
Southwest	2.318	2.318	2.318
West	4.674	4.674	4.674
Plains	3.283	3.283	3.283
Midwest			
Midwest	1.843	1.843	1.843
Southwest	3.254	3.254	3.254
Plains	2.752	2.752	2.752
West			
Midwest	3.085	3.085	3.085
Southwest	2.981	2.981	2.981
West	2.182	2.182	2.182
Plains	2.225	2.225	2.225

The costs of transporting hamburger steaks and roasts were estimated by Ward and Farris (1989) (see Appendix B Table B.9). The cost per mile of transporting the retail cuts declines as the distance traveled increases. Levels of live animal shrinkage during transfer from one production stage to another and from one supply region to another are shown in Table 5.12. The shrinkage on the shipment of hamburger, roasts and steaks from supply to demand regions is set at .04%.

An interregional weight adjustment is used to account for the cost incurred of keeping an animal for a longer or shorter period of time in a production activity because it is larger or smaller than the beginning weight for that animal. At the slaughter-processing stage it adjusts the costs incurred because the quantity of primal cuts produced is greater or less than typical in a region depending on whether the live animal coming in is heavier or lighter than the typical animal slaughtered in that supply region. It is possible for this to occur because there are differences in weights of animals at the same stage of production between supply regions (see Table 5.13). Thus, when cattle are shipped from one region to another it may be necessary to keep the animal in the production activity for a longer or shorter period of time depending on whether it is heavier or lighter than the beginning weight for cattle used in the production activity in the region to which it is shipped.

TABLE 5.12 SHRINKAGE OF LIVE CATTLE DURING TRANSFER BETWEEN PRODUCTION STAGES AND SUPPLY REGIONS

Region	Southeast	Midwest	Southwest	West	Plains
			Nonfed Cattle[a]		
Southeast	.964	.913	.928	.890	.908
Midwest		.965	.922	.900	.943
Southwest			.959	.904	.932
West				.945	.912
Plains					.959
			Fed Cattle[b]		
Southeast	.965	.928	.931	.900	.926
Midwest		.964	.932	.912	.936
Southwest			.945	.926	.934
West				.945	.928
Plains					.945

Note: Shrinkage includes death loss in transit which is .04% for nonfed cattle and .05% for fed cattle.

[a]Nonfed cattle includes calves, stockers, and culls.

[b]Fed cattle includes 900 lb-1300 lb cattle shipped from feed lots.

TABLE 5.13 WEIGHT OF LIVE CATTLE.

Region	Fed				Nonfed			
	900 lb	1,100 lb	1,200 lb	1,300 lb	Yearlings	1 1/2 years	Calves	Culls
	cwt							
Southeast	8.98	10.98	11.98	12.98	6.48	8.58	4.33	8.75
Midwest	9.30	11.30	12.30	13.30	6.80	8.90	4.65	9.42
Southwest	8.55	10.55	11.50	12.55	6.05	8.15	3.90	9.00
West	8.80	10.80	11.60	12.80	6.30	8.40	4.15	9.57
Plains	8.95	10.95	11.95	12.95	6.45	8.55	4.30	9.68

The adjustment is necessary because the costs of the production activities are based on the typical beginning and ending weight of the cattle in a particular region.

The marketing margin accounts for costs incurred at the distributing stage. The margins used are shown in Table 5.14. They are not based on production budgets for distribution activities, but on the differences between the average retail price for hamburger, roasts and steaks in each of the demand regions and the shadow price for the sales activity constraint in the solution of the linear programming formulation of the model. The linear programming formulation of this model was obtained by fixing both the retail price and quantity demanded of roasts, steaks, and hamburger at the average level observed in the data set used to estimate the demand system.

A major portion of beef is consumed away from the home. In order to account for this in the model the level of away from home consumption in each region was fixed at a predetermined level. The levels of away from home consumption are reported in Table 5.15. The levels were estimated by using the LP formulation of the model where prices for beef were fixed. In the first step the level of household consumption in each region was fixed at the mean of the data used in the demand system estimation. In the second step household consumption was not fixed so that production was only constrained by the size of the cow herd. Then the

TABLE 5.14 MARKETING MARGIN ON RETAIL CUTS IN DEMAND REGIONS.

Region	Ham-burger	Roast	Steak
		$/cwt	
Northeast	0.59	84.16	119.96
Midwest	1.46	77.94	36.53
South	8.20	91.78	0.77
West	9.10	104.38	85.48

TABLE 5.15. ANNUAL AWAY FROM HOME CONSUMPTION

Region	Roast	Steak	Ham-burger
	(000,000 cwt)		
Midwest	1.4934	1.8864	4.4801
West	1.0278	1.6929	3.3253
Northeast	1.5296	1.7382	3.6850
South	1.7957	3.4916	4.6887

total quantity of beef produced in the first step was subtracted from the total quantity of beef produced in the second step. This is the estimate of total away from home consumption. The total quantity of beef consumed away from home was distributed to the various regions based on each regions share of total population. Finally, each regions away from home consumption of beef was allocated among the beef cuts according to each cuts share of total beef consumption in the respective regions.

The level of beef imported was set at 1,446.34 million lbs. This represents the average level of beef imported from 1982-1986 (USDA, 1989). Since the U.S. is a net importer of hamburger all beef is imported as hamburger in the model. In addition, hamburger imports were restricted to the South and West demand regions. No beef is permitted to be exported during the base version of the model.

CHAPTER 6
BASE RESULTS AND SIMULATIONS

In this chapter the base results obtained from the optimization model and the results of four simulations are reported. The base solution is reported in detail while only results for variables of interest are reported in the simulations.

The Base Run

The maximum level of net social benefit (NSB) is -8.81×10^{-11}. The sign of this variable is unexpected as one would expect the optimal value of NSB to be positive at its maximum point. The negative sign is most likely caused by the different scales used to measure the areas under the demand curves and the areas under the supply curves. The demand functions use a logarithmic scale while costs are measured using the normal scale of measure. Thus, the area under the supply curves have a much greater magnitude than the area underneath the demand curve. Given that the main purpose of the objective function is to permit the constrained optimization model to simulate behavior in the beef sector there is no particular interest in the value of NSB. However, for welfare analysis it might be better to

have both the areas under the demand and supply curves measured on the same scale.

The optimal level of household consumption and retail prices are reported in Tables 6.1, 6.2 and 6.3. Note should be taken that the level of consumption reported reflects the level consumed for one month. The levels of the variables reported in these tables are consistent with the levels for quantity consumed and prices reported in the data set used to estimate the demand system.

The quantity of roast, steak and hamburger produced in each region and the amount transported from the supply regions to the demand regions are reported in Tables 6.4 and 6.5. The results show that the Midwest, Southwest and the Plains regions are the major suppliers of fresh beef. The dominance of the Midwest region over the rest is mainly due to the fact that it possesses the largest slaughtering capacity. The Midwest supplies all four of the demand regions. Both the Southeast and the Southwest supply all of the beef they produce to the South demand region. The West supplies beef only to the West while the Plains region supplies beef to the West and to the Northeast.

The quantity of weaned calves and beef culls produced and the transfer of calves to the other stages of production are reported in Tables 6.6-6.7. The quantity of calves produced is fixed as the size of the breeding herd and the calving rate have been set exogenously. The calves produced

TABLE 6.1. HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(lbs/month)			
Midwest	1.579	1.988	4.327	7.894
West	1.269	1.984	4.075	7.328
Northeast	1.771	1.930	3.970	7.671
South	1.514	2.865	3.861	8.240
Average	1.058	2.192	4.058	7.783

TABLE 6.2. REGIONAL CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(000,000 lbs/month)			
Midwest	37.864	47.682	103.770	189.316
West	26.299	41.095	84.417	151.811
Northeast	39.419	42.972	88.381	170.772
South	46.230	87.490	117.900	251.620
Total	149.812	219.239	394.468	763.519

TABLE 6.3. PRICE OF BEEF IN DEMAND REGIONS.

Region	Roast	Steak	Ham-burger
	($/lb)		
Midwest	2.262	2.716	1.650
West	2.547	3.243	1.732
Northeast	2.345	3.603	1.659
South	2.418	2.355	1.732

TABLE 6.4. QUANTITY OF BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(000,000 cwt)		
Southeast	0.132	0.159	0.814	1.101
Midwest	16.142	26.125	34.479	76.746
Southwest	4.184	5.046	6.686	15.916
West	0.394	0.472	2.425	3.291
Plains	3.963	4.779	6.690	15.432
Total	24.816	36.581	51.094	112.486

TABLE 6.5. QUANTITY OF BEEF CUTS SHIPPED.

Region	Roast	Steak	Hamburger
		(cwt)	
Southeast.South[a]	132,336	158,512	814,378
Midwest.Midwest	6,288,590	7,925,229	17,637,460
Midwest.West	-	1,648,972	-
Midwest.Northeast	6,520,685	7,182,183	8,195,359
Midwest.South	3,332,484	9,368,850	8,645,746
Southwest.South	4,184,496	5,045,967	6,686,815
West.West	394,082	472,033	2,425,123
Plains.West	3,963,931	4,779,363	-
Plains.Northeast	-	-	6,690,781

[a]Indicates the region shipped from and the region shipped to.

TABLE 6.6. WEANED CALVES AND CULLS PRODUCED.

Region	Cull	Calf
	(Head)	
Southeast	708,520	4,180,268
Midwest	1,564,248	6,815,652
Southwest	1,090,656	5,725,944
West	349,305	1,171,201
Plains	791,424	3,066,768

TABLE 6.7. CALVES TRANSFERRED TO STOCKER AND FINISHING STAGE.

Region	Feedlot	Stocker
	(Head)	
Southeast.Southwest	4,180,268	0
Midwest.Midwest	6,815,652	0
Southwest.Southwest	2,748,956	0
Southwest.Plains	2,976,987	0
West.Plains	1,171,201	0
Plains.Plains	3,066,768	0

in the Southeast are transferred to the finishing stage in the Southwest. The Southwest in turn transfers a portion of the calves it produces to the finishing stage in the Plains region. All the calves produced in the Midwest and Plains regions are transferred to the finishing stage in their respective regions while the calves produced in the West are transferred to the finishing stage in the Plains region. The movement of calves from the Southeast to the Southwest and from the Southwest to the Plains is typical of the observed pattern of feeder calf movements between supply regions (Ward, 1979).

In none of the supply regions are calves placed in the stocker activity before they are transferred to the finishing stage. This does not correspond to common practice in the beef sector. The primary reason why the stockering stage is not used in the model is that the cost of gain in the feedlot for stockered cattle is much higher than the cost of gain on feedlot for calves placed directly on the feedlot. This makes it uneconomical to stocker calves. This result indicates that the budgets for finishing stockered cattle need to be evaluated to determine whether the costs associated with these activities are too high.

The quantity of fed beef produced and the transfer of fed beef to the slaughtering-processing stage are reported in Tables 6.8-6.10. Only the Plains, Midwest and Southwest regions produce fed beef. The Plains region is the largest

TABLE 6.8. CATTLE USED IN THE FEEDLOT.

Region	Calf
	—(Head)—
Midwest	6,577,104
Southwest	6,515,537
Plains	6,783,719
Total	19,876,360

TABLE 6.9. FED CATTLE PRODUCED.

Region	900 lb	1,100 lb	Total
		(Head)	
Midwest	-	6,577,104	6,577,104
Southwest	-	6,515,537	6,515,537
Plains	6,783,719	-	6,783,719
Total	6,783,719	13,692,641	19,876,360

TABLE 6.10. FINISHED CATTLE SHIPPED TO SLAUGHTER.

Region	900 lb	1,100 lb
	(Head)	
Midwest.Midwest	-	6,577,104
Southwest.Midwest	-	3,870,034
Southwest.Southwest	-	2,645,502
Plains.Midwest	3,789,792	-
Plains.Plains	2,993,926	-

producer of fed beef and feeds them out at 900 lbs. Both the Midwest and the Southwest regions finish cattle at 1,100 lbs. The average weight of the cattle finished in the model is 1,033 lbs.

Both the Southwest and Plains regions transfer more than half of their fed cattle to the Midwest region to be slaughtered. The Midwest region slaughters all the fed beef it produces.

The transfer of beef culls to slaughter is reported in Table 6.11. The Southeast region retains a portion of its beef culls for slaughter and transfers the remainder to the Midwest and Southwest regions. The Southwest also retains a portion of its beef culls and transfers the remainder to the Plains regions. However, it remains a net importer of beef culls. The Midwest, Plains and West regions do not transfer any beef culls out of their respective regions.

The quantity of dairy culls transferred between regions is reported in Table 6.12. All the available dairy culls are utilized in the model. There are no transfers of dairy culls between regions.

The quantity of cattle slaughtered is reported in Table 6.13. The Midwest region slaughters the most cattle. It slaughters 900 lb. and 1,100 lb. fed cattle and culls. The Southwest region slaughters 1,100 lb. fed cattle and culls and the Plains region slaughters 900 lb. fed cattle

TABLE 6.11. BEEF CULLS SHIPPED TO SLAUGHTER.

Region	Cull
	—(Head)—
Southeast.Southeast	13,612
Southeast.Midwest	158,920
Southeast.Southwest	535,986
Midwest.Midwest	1,564,248
Southwest.Southwest	636,618
Southwest.Plains	454,037
West.West	349,305
Plains.Plains	791,424

TABLE 6.12. DAIRY CULLS SHIPPED TO SLAUGHTER.

Region	Cull
	—(Head)—
Southeast.Southeast	331,200
Midwest.Midwest	2,332,600
Southwest.Southwest	200,300
West.West	608,400
Plains.Plains	122,900

TABLE 6.13. CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
		(Head)		
Southeast	-	-	332,399	332,399
Midwest	3,547,246	9,947,200	3,905,552	17,399,998
Southwest	-	2,500,000	1,300,000	3,800,000
West	-	-	905,031	905,031
Plains	2,829,260	-	1,300,000	4,129,260
Total	6,376,506	12,447,200	7,742,982	26,566,688

and culls. The Southeast and West regions slaughter only culls. The average weight of cattle slaughtered in the model is 1,015 lbs. This compares to an average weight of 1,093 lbs. reported from 1983-87 (USDA, 1989).

The quantity of fabricated cuts produced in each region and their allocation to roast, steak, and hamburger production are reported in Tables 6.14-6.16. Each region uses the full amount of lean and medium trim available. In the Midwest region roast is also used in the production of hamburger. This result reflects the growing importance of hamburger in household expenditures for beef and the declining importance of roasts.

The quantity of hamburger imported into the West and South is reported in Table 6.17. Considerably more hamburger is imported into the West than into the South.

Scenarios

The use of the model to simulate sector response to changes in economic conditions raises a question concerning the limitations placed on the model's ability to portray the sector's behavior because the size of the breeding herd has been fixed. It is true that by fixing the size of the breeding herd the manner in which the sector can respond is limited by the fact that the size of the breeding herd cannot be increased.

There are four factors, however, which when taken into account suggest that fixing the size of the breeding herd

TABLE 6.14. PRIMAL CUTS PRODUCED.

Region	Roast	Steak	Lean Trim	Medium Trim	Fat and Bone
	(cwt)				
Southeast	132,336	158,512	770,751	43,627	349,019
Midwest	21,656,720	26,125,240	18,640,440	10,323,160	29,679,390
Southwest	4,184,496	5,045,967	4,725,463	1,961,351	6,021,471
West	394,082	472,033	2,295,206	129,917	1,039,338
Plains	3,963,931	4,779,363	4,843,690	1,847,090	5,797,834

TABLE 6.15. PRIMAL CUTS ALLOCATED TO HAMBURGER.

Region	Roast	Lean Trim	Medium Trim
		(cwt)	
Southeast	-	770,751	43,627
Midwest	5,514,962	18,640,440	10,323,160
Southwest	-	4,725,463	1,961,351
West	-	2,295,206	129,917
Plains	-	4,843,690	1,847,090

TABLE 6.16. PRIMAL CUTS ALLOCATED TO RETAIL.

Region	Roast	Steak
	(cwt)	
Southeast	132,336	158,512
Midwest	16,141,760	26,125,240
Southwest	4,184,496	5,045,967
West	394,082	472,033
Plains	3,963,931	4,779,363

TABLE 6.17. QUANTITY OF HAMBURGER IMPORTED.

Region	Hamburger
	(cwt)
West	11,127,200
South	3,336,201

is not unreasonably restrictive, at least in the medium run. First, changing the number of calves produced is not the only way for beef production to be increased or decreased. It can also be increased or decreased by adjusting the size of the cattle produced. The decline in the size of cattle produced during the last decade suggests that the sector has responded to declining demand for beef by doing just that. Second, the model is structured so that all calves produced do not need to be utilized if they are not needed. Third, while the number of calves and culls produced is fixed the total cost of producing them is not fixed in the model but varies with the number of calves or culls actually used. Furthermore the calves and culls are priced into the model at market prices. Fourth, due to the long lag period involved to expand the size of the cow herd the sector cannot adjust cow numbers instantaneously so that in the medium run, say five years, a fixed breeding herd may better reflect the sector's response to changing conditions than a breeding herd that is endogenously determined. Thus, one can see that by fixing the size of the breeding herd that costs of producing beef are not unduly distorted and that, in the medium, run the ability of the sector to increase or decrease production is not unduly restricted.

Scenario 1

In the first scenario the quantity of poultry consumed is increased to reflect projected levels of poultry consumption five years from now. The new level of poultry consumption was determined by taking the current level of poultry consumption in the base model and using the average rate of growth in poultry production from 1980-86 to project out five years.

From 1980-86 chicken production increased by an annual rate of 2.3% (USDA, 1989). This projects to an increase in chicken consumption of 11.5% over a period of five years. During this same time period turkey consumption increased at an annual rate of 4.2%. This rate projects to an increase in the level of turkey consumption over a five-year period of 21%. Based on these projections the levels of whole chicken and chicken parts consumption in the model were increased by 12%, while the level of other poultry consumption in the model was increased by 21%.

Given the negative sign on the poultry parameters in the beef demand equations an increase in the quantity of poultry consumed will cause the price of all the beef products to decrease. The decrease in the price of beef will in turn reduce profits to producers and cause the quantity of beef produced to decline. Thus, the increase in poultry consumption shifts the beef demand equations inward. The inward shift in the demand for beef, especially in the

case of roasts, is tempered by the cross-quantity effects between the beef products.

The new equilibrium level of household consumption is shown in Table 6.18. The increase in poultry consumed causes the level of all beef products to fall as shown in Table 6.19. The decline in consumption on an annual basis is greatest for hamburger (0.873 lbs.), followed by steak (0.707 lbs.) and then by roasts (0.248 lbs.).

The pattern of decline in consumption levels of roast, steak and hamburger differs among the demand regions. In the West, steak declined by 4.3%, hamburger by 1.5%, and roasts by 1.0% (see Table 6.20). The pattern of decline was similar in the Midwest but to a somewhat lesser extent. In the Northeast region it was hamburger which declined the most, then steak and then roasts, while in the South the order was reversed as roasts declined the most followed by steak and then hamburger.

The decline in household consumption of beef translated into a decline in the quantity of beef produced of 181.7 million lbs. The quantity of beef produced, the amount transported from each supply region to the demand regions and the change in the value of these variables obtained under Scenario 1 compared to their values in the base run are shown in Tables 6.21-6.26. Total production of roast declined by 27.34 million lbs., steak by 69.94 million lbs. and hamburger by 81.93 million lbs. On a total weight

TABLE 6.18. SCENARIO 1: HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger
	(lbs/month)		
Midwest	1.557	1.934	4.258
West	1.257	1.897	4.014
Northeast	1.769	1.881	3.842
South	1.469	2.819	3.828

TABLE 6.19. SCENARIO 1: CHANGE IN HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(lbs/year)			
Midwest	-0.264	-0.648	-0.828	-1.740
West	-0.144	-1.040	-0.732	-1.916
Northeast	-0.024	-0.588	-1.536	-2.148
South	-0.540	-0.522	-0.396	-1.488
Average	-0.243	-0.707	-0.873	-1.823

TABLE 6.20. SCENARIO 1: PERCENTAGE CHANGE IN HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(%)			
Midwest	-1.4	-2.7	-1.6	-1.8
West	-1.0	-4.3	-1.5	-2.2
Northeast	-0.1	-2.5	-3.2	-3.3
South	-3.0	-1.6	-0.9	-1.9
Average	-1.3	-2.7	-1.8	-2.0

TABLE 6.21. SCENARIO 1: QUANTITY OF BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(000,000 cwt)		
Southeast	0.1271	0.1523	0.7822	1.0616
Midwest	15.9070	25.4720	33.6940	75.0730
Southwest	4.1845	5.0460	6.6868	15.9173
West	3.9408	0.4720	2.4251	6.8379
Plains	3.9307	4.7392	6.6597	15.3296
Total	28.0901	35.8815	50.2478	114.2194

TABLE 6.22. SCENARIO 1: CHANGE IN QUANTITY OF BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(000,000 lbs)		
Southeast	-0.490	-0.670	-3.180	-4.34
Midwest	-23.500	-65.300	-78.500	-167.300
Southwest	0.000	0.000	0.000	0.000
West	0.000	0.000	0.000	0.000
Plains	-3.320	-4.020	-3.110	-10.450
Total	-27.340	-69.945	-81.931	-181.700

TABLE 6.23. SCENARIO 1: PERCENTAGE CHANGE IN QUANTITY OF BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(%)		
Southeast	-4.0	-4.0	-4.0	-4.0
Midwest	-1.5	-2.5	-2.3	-2.2
Southwest	0.0	0.0	0.0	0.0
West	0.0	0.0	0.0	0.0
Plains	-0.8	-0.8	-0.5	-0.7
Total	-1.1	-1.9	-1.6	-1.6

TABLE 6.24. SCENARIO 1: QUANTITY BEEF SHIPPED.

Region	Roast	Steak	Hamburger
	(cwt)		
Southeast.South	127,112	152,255	782,228
Midwest.Midwest	6,223,570	7,763,104	17,430,960
Midwest.West	-	1,463,834	-
Midwest.Northeast	6,516,026	7,045,634	7,868,366
Midwest.South	3,167,711	9,199,442	8,394,997
Southwest.South	4,184,496	5,045,967	6,686,815
West.West	394,082	472,033	2,425,123
Plains.West	3,930,685	4,739,233	-
Plains.Northeast	-	-	6,659,731

TABLE 6.25. SCENARIO 1: CHANGE IN QUANTITY OF BEEF SHIPPED.

Region	Roast	Steak	Hamburger
	(cwt)		
Southeast.South	-5,224	-6,257	-32,150
Midwest.Midwest	-65,019	-162,214	-206,500
Midwest.West	-	-185,137	-
Midwest.Northeast	-4,658	-136,549	-326,993
Midwest.South	-164,773	-169,407	-250,748
Southwest.South	0	0	0
West.West	0	0	0
Plains.West	-33,246	-40,129	-
Plains.Northeast	-	-	-31,049

TABLE 6.26. SCENARIO 1: PERCENTAGE CHANGE IN QUANTITY OF BEEF SHIPPED.

Region	Roast	Steak	Hamburger
		(%)	
Southeast.South	-4.0	-4.0	-4.0
Midwest.Midwest	-1.0	-2.0	-1.2
Midwest.West	-	-11.2	-
Midwest.Northeast	0.0	-1.9	-4.0
Midwest.South	-4.9	-1.8	-2.9
Southwest.South	0.0	0.0	0.0
West.West	0.0	0.0	0.0
Plains.West	-0.8	-0.8	-
Plains.Northeast	-	-	-0.5

basis the quantity of beef produced declined the most in the Midwest, then the Plains and then the Southeast. There was no change in the quantity of beef produced in either the Southwest or the West regions. In terms of percentages, the Southeast was the region hardest hit by the decline in the levels of beef consumption as its production of beef declined by 4%.

The pattern of shipments of beef from the supply regions to the demand regions remain unchanged. The greatest decline in shipments occurred in the amount shipped from the Midwest to the West (see Tables 6.25 and 6.26). The level of hamburger imported into the West declined by 1.4% but the level imported into the South increased by 4.6% (Table 6.27).

The number of cattle slaughtered in each region under Scenario 1 and the change number of cattle slaughtered from the base are reported in Tables 6.28 and 6.29. The decline in quantity of beef produced does not translate directly into a decline in the number of cattle slaughtered. While the Midwest region had the greatest decline in quantity of beef produced there was no decline in the number of cattle slaughtered. This implies that the average weight of cattle slaughtered in the Midwest region declined which in turn implies that the average weight of finished cattle has declined.

TABLE 6.27. SCENARIO 1: QUANTITY OF HAMBURGER IMPORTED.

Region	Hamburger	Change	
	——(cwt)——	—(cwt)—	(%)
West	10,974,970	-152,230	-1.4
South	3,488,434	+152,233	-4.7

TABLE 6.28. SCENARIO 1: CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
	——————(Head)——————			
Southeast	-	-	319,276	319,276
Midwest	5,198,476	8,283,542	3,917,981	17,399,999
Southwest	-	2,500,000	1,300,000	3,800,000
West	-	-	905,031	905,031
Plains	2,801,524	-	1,300,000	4,101,524
Total	8,000,000	10,783,542	7,742,288	26,525830

TABLE 6.29. SCENARIO 1: CHANGE IN CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
	——————(Head)——————			
Southeast	-	-	-13,123	13,123
Midwest	1,642,230	-1,663,658	12,427	-9,001
Southwest	-	0	0	0
West	-	-	0	0
Plains	-27,736	-	0	-27,736
Total	1,614,494	-1,663,658	695	-23,614

The number of cattle finished, their weight, and the change in quantity finished are shown in Tables 6.30 and 6.31. The total number of cattle finished declined by 50,200 head. This represents less than 0.3% of the quantity finished in the base model. However, while the decline nationally is insignificant there were major changes in the quantity of cattle finished in the Southwest and Plains regions. The level of cattle finished in the Southwest dropped 1.785 million head or by 27.4%. while the number of cattle finished in the Plains region increased by 1.7348 million head or 25.5%. This shift in level of cattle finished in the supply regions caused the average weight of finished cattle to drop from 1,033 lbs. in the base to 1,014 lbs. This is because cattle are finished at a weight of 900 lbs. in the Plains and a weight of 1,100 lbs. in the Southwest.

Table 6.32 gives the weight of finished cattle shipped to slaughter. As shown in Table 6.33 the quantity of 1,100 lb. fed cattle shipped to the Midwest from the Southwest declined by 1.785 million head while the quantity of 900 lb. fed cattle shipped from the Plains to the Midwest increased by 1.764 million. This result explains how the Midwest region can have a decline in the quantity of beef produced and yet have no decline in the number of cattle slaughtered.

The number of weaned calves utilized in each supply region did not change (see Table 6.34) even though the

TABLE 6.30. SCENARIO 1: FED CATTLE PRODUCED.

Region	900 lb	1,100 lb
	(Head)	
Midwest	-	6,577,104
Southwest	-	4,730,495
Plains	8,518,504	-

TABLE 6.31. SCENARIO 1: CHANGE IN CATTLE FINISHED.

	900 lb		1,100 lb		Total	
Region	Head	Percent	Head	Percent	Head	Percent
	(000,000)		(000,000)		(000,000)	
Midwest	-	-	0.000	0.0	0.000	0.0
Southwest	-	-	-1.785	-27.4	-1.785	-27.4
Plains	1.734	25.5	-	-	1.734	25.5
Total	1.734	25.5	-1.785	-27.0	-0.050	-0.3

TABLE 6.32. SCENARIO 1: FINISHED CATTLE SHIPPED TO SLAUGHGHTER.

Region	900 lb	1,100 lb
	(Head)	
Midwest.Midwest	-	6,577,104
Southwest.Midwest	-	2,084,993
Southwest.Southwest	-	2,645,502
Plains.Midwest	5,553,927	-
Plains.Plains	2,964,576	-

TABLE 6.33. SCENARIO 1: CHANGE IN NUMBER OF FINISHED CATTLE SHIPPED TO SLAUGHTER.

Region	900 lb		1,100 lb	
	Head	Percent	Head	Percent
Midwest.Midwest	-	-	0	0.0
Southwest.Midwest	-	-	-1,785,041	-46.1
Southwest.Southwest	-	-	0	0.0
Plains.Midwest	1,764,135	46.5	-	-
Plains.Plains	-29,350	-1.0	-	-

TABLE 6.34. SCENARIO 1: CALVES SHIPPED TO FEEDLOT.

Region	Calves	Change	
		Head	Per-cent
Southeast.Southwest	4,180,268	0	0.0
Midwest.Midwest	6,815,652	0	0.0
Southwest.Southwest	887,598	-1,861,357	-67.7
Southwest.Plains	4,838,345	1,861,357	+62.5
West.Plains	1,171,201	0	0.0
Plains.Plains	3,066,768	0	0.0
Total	20,959,834	0	0.0

number of cattle finished declined. The reduction in the number of cattle finished occurred because there were less calves retained in the Southwest than during the base run and the quantity of calves shipped from the Southwest to the Plains region was increased by 1.861 million. However, there is a higher rate of shrink (mainly due to death loss in transit) for cattle shipped from the Southwest to the Plains than from those retained in the Southwest.

What do these changes occurring in the weights of cattle imply about the impact of increased levels of poultry consumption on returns to beef producers? At a national level the implication is that there will not be a whole lot of change. The reduction in the level of beef produced only amounts to a 1% change in the level of production compared to the base model. At a regional level, however, the results indicate that meat processors in the Southeast suffer some losses as the level of their production is cut back by 4%. The hardest hit segment of the beef sector will be feedlot operators in the Southwest region where production declines by 27.4%.

Scenario 2

In Scenario 2, the level of poultry consumed is increased by 40%. This is approximately the percentage by

which the level of poultry consumption increased from 1975-1985 (USDA, 1987). Hopefully, the results will provide some insight into what has occurred in the pattern of meat consumption during this period. If the decline in the price of poultry relative to the price of beef is the reason per capita level of beef consumed has decreased then the increase in the level of poultry consumption by 40% should cause the quantity of beef consumed as determined by the model to decline by the same amount as the level of beef consumption declined from 1975-1985. If the levels of beef consumption obtained from the model do not decline by this amount then this provides an indication that the decline in the consumption of beef is due to other factors such as a change in preferences or change in income.

The level of household consumption of beef and the change which has incurred in its level from the base model are shown in Tables 6.35-6.37. The per capita level of beef consumption declined on an annual basis by an average of 1.93 lbs. This figure was derived by dividing the average total decline in beef consumption by 2.5, the average household size, and then multiplying this amount by 12, the number of months in the year. This represents a 5.2% decline in the level of beef consumed which is approximately one-half of the amount by which beef declined from 1975-1985.

TABLE 6.35. SCENARIO 2: HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(lbs/month)			
Midwest	1.490	1.901	4.103	7.494
West	1.233	1.803	3.884	6.920
Northeast	1.762	1.827	3.594	7.183
South	1.379	2.780	3.772	7.931
Average	1.466	2.078	3.838	7.382

TABLE 6.36. SCENARIO 2: CHANGE IN HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(lbs/month)			
Midwest	-0.089	-0.087	-0.224	-0.400
West	-0.036	-0.181	-0.191	-0.408
Northeast	-0.009	-0.103	-0.376	-0.488
South	-0.135	-0.085	-0.089	-0.309
Average	-0.067	-0.114	-0.220	-0.401

TABLE 6.37. SCENARIO 2: PERCENTAGE CHANGE IN HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(%)			
Midwest	-5.60	-4.4	-5.2	-5.1
West	-2.8	-9.1	-4.7	-5.6
Northeast	-0.5	-5.3	-9.5	-6.4
South	-8.9	-3.0	-2.3	-3.8
Average	-0.067	-0.114	-0.220	-5.2

This result indicates that the decline in per capita levels of beef consumption observed during the 1975-1985 time period was due in part to a decline in the price of chicken relative to the price of beef. However, it also indicates that the decline in beef consumption was not due solely to the decline in the price of poultry. Close to 50% of the decline in beef consumption was caused by other factors such as a shift in consumers preferences.

The increase in poultry consumption has also led to a decrease in the price of roasts, steaks, and hamburger (see Table 6.38). The decline in the price of beef is less than 1%. This also indicates that the decline in beef consumption is due to factors other than a decline in the price of poultry. The price of beef in real terms has declined more than this amount. Thus, factors other than prices of substitute goods must have caused the demand for beef to shift inward.

The quantity of beef produced and the change in the quantity of beef produced under this scenario from the base level are reported in Tables 6.39-6.41. All the supply regions, except for the Plains region, produce less beef than produced before. The greatest reductions in beef production occur in the Southeast (60.0%) and the West (65.5%). The increase in the level of beef production in the Plains region is a continuation of the process noted on in Scenario 1 where the number of 900 lb. fed cattle

TABLE 6.38. SCENARIO 2: PRICE OF BEEF IN DEMAND REGIONS.

Region	Roast	Steak	Ham-burger
	($/lb)		
Midwest	2.253	2.698	1.644
West	2.538	3.225	1.725
Northeast	2.336	3.584	1.652
South	2.409	2.337	1.725

TABLE 6.39. SCENARIO 2: QUANTITY PROCESSED MEAT PRODUCED.

Region	Roast	Steak	Hamburger	Total
	(000,000 cwt)			
Southeast	0.053	0.063	0.326	0.442
Midwest	15.415	24.992	32.812	74.219
Southwest	4.184	5.046	6.686	15.917
West	0.143	0.172	0.884	1.200
Plains	4.121	4.969	6.837	15.927
Total	23.917	35.241	48.546	107.710

TABLE 6.40. SCENARIO 2: CHANGE IN QUANTITY PROCESSED MEAT PRODUCED.

Region	Roast	Steak	Ham-burger	Total
	(000,000 cwt)			
Southeast	-0.079	-0.095	-0.488	-0.659
Midwest	-0.727	-1.330	-0.667	-2.570
Southwest	0.000	0.000	0.000	0.000
West	-0.250	-0.299	-1.540	-2.091
Plains	0.157	0.189	0.146	0.496
Total	-0.899	-1.340	-2.547	-4.776

TABLE 6.41. SCENARIO 2: PERCENTAGE CHANGE IN QUANTITY BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
	(%)			
Southeast	-59.8	-59.7	-60.0	-60.0
Midwest	-4.4	-4.3	-2.0	-3.3
Southwest	0.0	0.0	0.0	0.0
West	-63.5	-63.3	-62.8	-65.5
Plains	4.0	4.0	2.2	3.2
Total	-3.6	-3.7	-5.0	-4.2

produced has increased and the level of 1,100 lb. fed cattle produced has decreased in response to a decrease in the demand for beef. The Plains region has a comparative advantage over both the Midwest and the Southwest in the production of 900 lb. fed cattle. Consequently, while cattle production has declined in the Southwest region some 40.4% it has increased in the Plains region by 37.8% (see Tables 6.42-6.44). For the country as a whole, the quantity of cattle finished as a result of the increase in poultry consumption dropped by 74,222 head. This amounts to a reduction in the number of feeder cattle of less than 1%.

The total amount of cattle slaughtered under this scenario declined by 643,000 head (see Tables 6.45-6.47). The reduction is due mostly to a net reduction in the quantity of culls slaughtered of 585,483 head.

Scenario 3

In Scenario 3 the level of hamburger imports is increased in order to determine its impact on domestic producers. Beef imports into this country are currently subject to quotas. However, the U.S government as part of its trade negotiations is arguing for a removal of all government subsidies to agricultural products. As a result imports of beef may not be subject to quotas in the near future.

In the base run the level of imported hamburger was fixed at 1.446 billion lbs. From 1983-1987 imports of beef

TABLE 6.42. SCENARIO 2: FED CATTLE PRODUCED.

Region	900 lb	1,100 lb	Total
		(Head)	
Midwest	-	6,577,104	6,577,104
Southwest	-	3,879,288	3,879,288
Plains	9,345,746	-	9,345,746
Total	9,345,746	10,456,392	19,802,138

TABLE 6.43. SCENARIO 2: CHANGE IN FED CATTLE PRODUCED.

Region	900 lb	1,100 lb	Total
		(000,000 head)	
Midwest	-	0.000	0.000
Southwest	-	-2.636	-2.636
Plains	2.562	-	2.562
Total	2.562	-2.636	-0.074

TABLE 6.44. SCENARIO 2: PERCENTAGE CHANGE IN FED CATTLE PRODUCED

Region	900 lb	1,100 lb	Total
		(%)	
Midwest	-	0.0	0.0
Southwest	-	-40.4	-40.4
Plains	37.8	-	37.8
Total	37.8	-19.3	-0.4

TABLE 6.45. SCENARIO 2: CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
		(head)		
Southeast	-	-	133,074	133,074
Midwest	5,815,450	7,490,217	4,094,332	17,399,999
Southwest	-	2,500,000	1,300,000	3,800,000
West	-	-	330,093	330,093
Plains	2,960,361	-	1,300,000	4,260,361
Total	8,775,811	9,990,217	7,157,499	25,923,527

TABLE 6.46. SCENARIO 2: CHANGE IN CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
		(000,000 Head)		
Southeast	-	-	-0.199	-0.199
Midwest	2.268	-2.457	0.189	0.000
Southwest	-	0.000	0.000	0.000
West	-	-	-0.575	-0.575
Plains	0.131	-	0.000	0.131
Total	2.399	-2.457	-0.585	-0.643

TABLE 6.47. SCENARIO 2: PERCENTAGE CHANGE IN CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
		(%)		
Southeast	-	-	-60.0	-60.0
Midwest	64.0	-24.7	4.8	0.0
Southwest	-	0.0	0.0	0.0
West	-	-	-63.5	-63.5
Plains	4.6	-	0.0	3.2
Total	37.6	-19.7	-7.5	-2.4

increased by 16% from 1.415 billion lbs. to 1.643 billion lbs. (USDA, 1989). In this scenario the level of hamburger imported is increased by 16%.

An increase in the level of imported hamburger will cause the price of hamburger to decline because it is cheaper than domestically produced hamburger. The decline in the price of hamburger will cause the level of hamburger consumed by households to increase. From the parameter values on the estimated demand systems it is known that an increase in the quantity of hamburger consumed will cause the price of both steak and roast to decline. The decline in the price of roasts and steaks will in turn cause households to increase their level of consumption of steaks and roasts. Thus, it is possible that the loss of hamburger sales to imported hamburger will be offset by increased consumption of roasts and steak. However, the ability of producers to substitute away from hamburger production and increase production of steaks and roasts is limited by the fact that steaks and roasts are only available from a carcass in a fixed proportion.

The impact of a 16% increase in imports of hamburger on the level of household consumption of beef is shown in Tables 6.48-6.50. As expected the quantity of hamburger consumed increased as did the consumption of roasts. However, the consumption of steak decreased. Total consumption of beef increased on average by 0.032 lbs. per month.

TABLE 6.48. SCENARIO 3: HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
		(lbs)		
Midwest	1.596	1.946	4.395	7.937
West	1.273	1.955	4.130	7.358
Northeast	1.784	1.914	4.010	7.708
South	1.524	2.827	3.906	8.257
Average	1.544	2.161	4.110	7.815

TABLE 6.49. SCENARIO 3: CHANGE IN HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
		(lbs)		
Midwest	0.017	-0.042	0.068	0.043
West	0.004	-0.029	0.055	0.030
Northeast	0.013	-0.016	0.040	0.037
South	0.010	-0.038	0.045	0.017
Average	0.011	-0.031	0.052	0.032

TABLE 6.50. SCENARIO 3: PERCENTAGE CHANGE IN HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
		(%)		
Midwest	1.0	-2.1	1.6	0.5
West	0.3	-1.5	1.3	0.4
Northeast	0.8	-0.8	1.0	0.5
South	0.7	-1.3	1.2	0.2
Average	0.7	-1.4	1.3	0.4

The increased levels of imported hamburger caused the price of hamburger and roasts to decline, but caused the price of steak to increase (see Tables 6.51 and 6.52). The increase in the price of steak explains why steak consumption declined.

The level of beef produced under Scenario 3 is reported in Table 6.53. In terms of aggregate beef production, the increase in imports caused production to decline by 203.4 million lbs. (see Table 6.54). This represents a 1.8% reduction from the base level of production (see Table 6.55). While the total reduction in beef production is small the effect on regional production varied dramatically. In the Southeast and the West output of beef declined by 57% and 50% respectively. In the Plains region, however, output increased by 4%.

The 1.8% decline in beef production led to a decline in the number of cattle slaughtered of 466,635 (see Tables 6.56 and 6.57). This amounts to 1.7% reduction in the quantity of cattle slaughtered in the base run. As occurred in the poultry scenarios the composition of the slaughter cattle was altered. The number of 900 lb. cattle slaughtered increased by 348,999 head (5.5%) and the number of 1,100 lb. cattle slaughtered declined by 355,908 head (2.9%) (see Tables 6.57 and 6.58).

The quantity of cattle finished and the change in quantity finished from the quantity finished in the base

TABLE 6.51. SCENARO 3: RETAIL PRICE OF BEEF.

Region	Roast	Steak	Ham-burger
	($/lb)		
Midwest	2.255	2.728	1.643
West	2.545	3.255	1.725
Northeast	2.337	3.614	1.652
South	2.411	2.367	1.725

TABLE 6.52. SCENARO 3: CHANGE IN RETAIL PRICE OF BEEF.

Region	Roast	Steak	Ham-burger
	($/lb)		
Midwest	-0.007	0.012	-0.007
West	-0.002	0.012	-0.007
Northeast	-0.008	0.011	-0.007
South	-0.007	0.012	-0.007

TABLE 6.53. SCENARIO 3: QUANTITY BEEF PRODUCED.

Region	Roast	Steak	Hamburger	Total
		(000,000 cwt)		
Southeast	0.057	0.069	0.354	0.480
Midwest	16.344	25.812	34.174	76.330
Southwest	4.184	5.046	6.686	15.916
West	0.198	0.237	1.219	1.654
Plains	4.168	5.026	6.881	13.075
Total	24.952	36.190	49.317	110.455

TABLE 6.54. SCENARIO 3: CHANGE IN BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(000,000 cwt)		
South	-0.074	-0.090	-0.460	-0.624
Midwest	0.202	-0.313	-0.305	-0.416
Southwest	0.000	0.000	0.000	0.000
West	-0.196	-0.235	-1.205	-1.636
Plains	0.204	0.247	0.191	0.642
Total	0.136	-0.391	-1.779	-2.034

TABLE 6.55. SCENARIO 3: PERCENTAGE CHANGE IN BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(%)		
Southeast	-56.0	-57.0	-57.0	-56.8
Midwest	1.0	-1.0	-1.0	-0.5
Southwest	0.0	0.0	0.0	0.0
West	-50.0	-50.0	-50.0	-50.0
Plains	5.0	5.0	2.9	4.1
Total	0.5	-1.0	-3.5	-1.8

TABLE 6.56. SCENARIO 3: CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
	(Head)			
Southeast	-	-	144,826	144,826
Midwest	3,725,505	9,591,292	4,083,202	17,399,999
Southwest	-	2,500,000	1,300,000	3,800,000
West	-	-	455,229	455,229
Plains	3,000,000	-	1,300,000	4,300,000
Total	6,725,505	12,094,292	7,283,257	25,955,373

TABLE 6.57. SCENARIO 3: CHANGE IN CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
	(000,000 head)			
Southeast	-	-	-0.187	-0.187
Midwest	0.178	-0.356	0.178	0.000
Southwest	-	0.000	0.000	0.000
West	-	-	-0.450	-0.450
Plains	0.171	-	0.000	0.171
Total	0.350	-0.356	-0.460	-0.467

TABLE 6.58. SCENARIO 3: PERCENTAGE CHANGE IN CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
	(000,000 head)			
Southeast	-	-	-56.0	-56.0
Midwest	5.0	-4.0	4.0	0.0
Southwest	-	0.0	0.0	0.0
West	-	-	-50.0	-50.0
Plains	6.0	-	0.0	6.0
Total	5.5	-2.9	-5.9	-1.7

model are shown in Tables 6.59-6.61. The total number of cattle finished declined by only 10,752 head (<0.1%). However, the number of cattle finished in the Southwest declined by 318,876 head (58.0%), while in the Plains region the number of cattle finished increased by 371,124 head (5.5%). As was the case with the composition of slaughter cattle the composition of fed cattle changed as the cattle in the Plains region were finished at 900 lbs. and the cattle in the Southwest were finished at 1,100 lbs. Thus, as the demand for feeder cattle decreases the cattle are fed out at lighter weights.

The disposition of the imported hamburger is shown in Table 6.62. The West's imports of hamburger increased by 11.6% and the level of the South's imports of hamburger increased by 23.4%. Despite the disparity in the percentage increase in imports the increase in imports in terms of weight was allocated evenly between the two regions.

Scenario 4

In the fourth scenario the impact of increased levels of beef exports on beef producers is examined. Historically, beef exports have not been large in comparison to total domestic production. In 1977 for example, exports of beef accounted for less than 0.5% of total U.S. beef production (USDA, 1989). However, during the last decade (1977-1987) beef exports have increased substantially and prospects for even greater expansion of beef exports are

TABLE 6.59. SCENARIO 3: FED CATTLE PRODUCED.

Region	900 lb	1,100 lb	Total
	(Head)		
Midwest	-	6,577,104	6,577,104
Southwest	-	6,133,661	6,133,661
Plains	7,154,843	-	7,154,843
Total	7,154,843	12,107,765	19,107,765

TABLE 6.60. SCENARIO 3: CHANGE IN FED CATTLE PRODUCED.

Region	900 lb	1,100 lb	Total
	(000,000 head)		
Midwest	-	0.000	0.000
Southwest	-	-0.382	-0.382
Plains	0.371	-	0.371
Total	0.371	-0.382	-0.011

TABLE 6.61. SCENARIO 3: PERCENTAGE CHANGE IN FED CATTLE PRODUCED.

Region	900 lb	1,100 lb	Total
	(%)		
Midwest	-	0.0	0.0
Southwest	-	-5.8	-5.8
Plains	5.5	-	5.5
Total	5.5	-2.7	<-0.1

TABLE 6.62. SCENARIO 3: QUANTITY OF HAMBURGER IMPORTED.

Region	Hamburger	Change	
	(cwt)	(cwt)	(%)
West	12,422,220	1,295,020	11.6
South	4,355,319	1,019,118	23.4

good. From 1977-1982 exports of beef doubled from 91.5 million lbs. to 188.9 million lbs. They nearly tripled again from 1982-1987 as they rose from 188.9 million lbs. to 465.1 million lbs. As a result of this expansion, exports of beef accounted for 2% of total production in 1987, causing beef producers to view increasing the level of beef exports as a means of offsetting loss of market share in domestic markets.

In order to look at the impact of increased levels of beef exports on household consumption of beef and on beef producers the model is altered to include the export of beef as a production activity. The demand for beef exports can be incorporated in two ways: (1) fixing the level of beef exported at a predetermined level or (2) using an export demand equation. For the analysis undertaken here the level of beef exports was fixed at a level of 1,395.3 million lbs. This represents three times the level of beef exports in 1987. In addition beef exports were limited to steaks and roasts as the U.S. is a net exporter of steaks and roasts and a net importer of hamburger.

The model, as presently set up is limited by the fact that the size of the breeding herd is fixed at a predetermined level rather than being endogenously determined within the model. As a consequence an increase in the level of beef exported cannot be met by increasing the number of cattle available but only through reducing domestic con-

sumption or increasing the size of cattle slaughtered or both. Given the slow response time involved in expanding beef production this limitation may not be too severe.

The increase in level of beef causes the overall demand for beef to increase. This result will in turn cause the domestic price of beef to increase as the amount of beef available in domestic markets is reduced. It will also cause beef producers to expand production in response to both the increased level of beef exports and the rise in domestic beef prices. Because the size of the breeding herd is fixed the quantity of beef produced can only be increased by increasing the weight of the cattle being produced. Thus, producers in supply regions with a comparative advantage in finishing higher weight cattle will see production increase while producers in other regions should see their level of production decline.

The level of household consumption of beef due to the increase in beef exports and the change which has occurred in these consumption levels from their base levels are reported in Tables 6.63-6.65. As expected the level of household consumption of beef declined as a result of an increase of beef exports. In this case the 6% increase in exports led to an average decline in beef consumption of 0.583 lbs. per month. This represents a 7.5% decline in beef consumption from the base level.

TABLE 6.63. SCENARIO 4: HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(lbs/month)			
Midwest	1.615	1.475	4.227	7.317
West	1.237	1.603	3.968	6.808
Northeast	1.747	1.693	3.699	7.139
South	1.477	2.298	3.762	7.537
Average	1.519	1.767	3.914	7.200

TABLE 6.64. SCENARIO 4: CHANGE IN HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(lbs/month)			
Midwest	0.036	-0.513	-0.100	-0.577
West	-0.032	-0.381	-0.107	-0.520
Northeast	-0.024	-0.237	-0.271	-0.532
South	-0.037	-0.567	-0.099	-0.703
Average	-0.014	-0.425	-0.144	-0.583

TABLE 6.65. SCENARIO 4: PERCENTAGE CHANGE IN HOUSEHOLD CONSUMPTION OF BEEF.

Region	Roast	Steak	Ham-burger	Total
	(%)			
Midwest	2.3	-25.8	-2.3	-7.3
West	-2.5	-19.2	-2.6	-7.1
Northeast	-1.4	-12.3	-6.8	-6.9
South	-2.4	-19.8	-2.6	-8.5
Average	-1.0	-19.4	-3.5	-7.5

The greatest decline occurred in the consumption of steak which dropped 19.4%. The consumption of hamburger declined even though exports of hamburger were not permitted. In fact, the decline in hamburger consumption was greater than the decline in consumption of roasts on both an absolute and a percentage basis.

On a regional basis the decline in steak consumption was greatest in the Midwest and lowest in the Northeast. The consumption of roasts actually increased in the Midwest. The decline in the consumption of hamburger was greatest in the Northeast and least in the Midwest.

Changes in the level of beef production are reported in Tables 6.66-6.68. The 6% increase in beef exports led to a 6% increase in the quantity of beef produced. This implies that the multiplier on the change in beef production due to a change in beef exported is one. Thus, the increase in export demand did not cause the domestic price of beef to increase high enough to cause domestic consumption of beef to decline enough to offset the impact of the increase export demand on beef production.

The production of roast increased the most, 23.5% while the overall level of hamburger production decreased by 3.3%. The production of beef increased the most in the Plains region, 409.62 million lbs. followed by the Midwest 375.9 million lbs. The level of production in the West was

TABLE 6.66. SCENARIO 4: QUANTITY OF BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(000,000 cwt)		
Southeast	0.093	0.111	0.570	0.774
Midwest	21.103	27.691	31.701	80.505
Southwest	3.471	4.182	7.471	15.124
West	0.394	0.472	2.425	3.291
Plains	5.577	6.728	7.224	19.528
Total	30.637	39.1835	49.3912	119.222

TABLE 6.67. SCENARIO 4: CHANGE IN QUANTITY OF BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(000,000 cwt)		
Southeast	-0.039	-0.048	-0.244	-0.327
Midwest	4.961	1.566	-2.778	3.759
Southwest	-0.714	-0.864	0.784	-0.791
West	0.0	0.0	0.0	0.0
Plains	1.613	1.949	0.533	4.096
Total	5.821	2.606	-1.703	6.736

TABLE 6.68. SCENARIO 4: PERCENTAGE CHANGE IN QUANTITY OF BEEF PRODUCED.

Region	Roast	Steak	Ham-burger	Total
		(%)		
Southeast	-29.8	-30.2	-30.0	-29.7
Midwest	30.7	6.0	-8.1	5.0
Southwest	-17.1	-17.1	11.7	-5.0
West	0.0	0.0	0.0	0.0
Plains	40.7	40.8	8.0	26.7
Total	23.5	7.1	-3.3	6.0

unchanged while the level of beef production in the Southwest and Southeast regions actually declined.

The increase in beef production observed in the Plains and Midwest regions was due to a change in the size of cattle slaughtered in these regions (Tables 6.69-6.70). The Plains and Midwest regions no longer slaughter 900 lb. cattle but only 1,100 lb. cattle and culls.

The change in size of cattle slaughtered reflects changes observed in the size of cattle finished (Tables 6.71-6.72). While the number of cattle finished increased less than 0.5% the number of cattle finished at 1,100 lbs. increased by 50.1% while the number of cattle finished at 900 lbs. declined by 100.0%. As a result of this shift to heavier finishing weight the number of cattle finished in the Southwest increased by 43.8% while the number finished in the Plains region decreased by 40.9%. Thus the feedlot operators in the Southwest benefit from an increase in beef exports while feedlot operators in the Plains region lose.

TABLE 6.69. SCENARIO 4: QUANTITY CATTLE SLAUGHTERED.

Region	1,100 lb	Cull	Total
	(Head)		
Southeast	-	232,712	232,712
Midwest	13,639,540	3,760,458	17,399,998
Southwest	1,821,134	1,978,865	3,799,999
West	-	905,031	905,031
Plains	3,423,163	876,836	4,299,999
Total	18,883,837	7,753,902	26,637,739

TABLE 6.70. SCENARIO 4: CHANGE IN QUANTITY CATTLE SLAUGHTERED.

Region	900 lb	1,100 lb	Cull	Total
		(Head)		
Southeast	-	-99,687	-99,687	-
Midwest	-3,547,246	3,692,340	-145,094	0
Southwest	-	-678,866	678,865	0
West	-	0	0	0
Plains	-2,829,260	3,423,163	-423,164	170,739
Total	-6,376,506	6,436,637	10,920	71,052

TABLE 6.71 SCENARIO 4: CATTLE FINISHED.

Region	1,100 lb
	—(Head)—
Midwest	6,577,104
Southwest	9,370,469
Plains	4,009,166
Total	19,956,739

TABLE 6.72 SCENARIO 4: CHANGE IN CATTLE FINISHED.

Region	900 lb	1,100 lb	Total
		(Head)	
Midwest	-	0	0
Southwest	-	2,854,932	2,854,932
Plains	-6,783,719	4,009,166	-2,774,553
Total	-6,783,719	6,864,098	80,379

TABLE 6.73 SCENARIO 4: PERCENTAGE CHANGE IN CATTLE FINISHED.

Region	900 lb	1,100 lb	Total
		(%)	
Midwest	-	0.0	0.0
Southwest	-	43.8	43.8
Plains	-100.0	N/A	-40.9
Total	-100.0	50.1	0.4

CHAPTER 7
SUMMARY AND CONCLUSIONS

The structure of the beef sub-sector is dynamic, responding to technological innovations in beef production and changes in household meat consumption patterns. It is important to be able to determine the impact of these changes in the economic environment on the structure of the sector so that both producers and government agencies can anticipate these changes and develop responses.

The purpose of this research was to develop a mathematical programming model of the U.S. beef sector which incorporates regional differences in production, endogenous price determination and interdependence of demand for meats. A linear activity analysis model is used to represent the beef production system at the regional level. The activity analysis model is integrated with a system of inverse demand equations for hamburger, steak and roasts. Thus, the model incorporates endogenous determination of prices, interdependence among meat products in the demand for meats, and regional representation of beef production.

The integration of systems of demand equations into mathematical programming model is problematic both in regards to satisfying mathematical conditions and to operationalizing the theoretical model. The theoretical

problems associated with incorporating demand systems into programming models are well known. However, the operational difficulties are not as well known due to the fact that the difficulties in overcoming the theoretical problems have limited the application of this methodology.

One theoretical problem, known as the integrability problem, is that demand systems derived from economic theory do not have mathematical properties which satisfy the mathematical conditions of the programming model. Solutions to the integrability problem developed until recently have either been computationally intractable or inadequate in their representation of the demand structure.

The methodology used in this dissertation solves the integrability problem by using a compensated demand system in place of an uncompensated system in the formulation of the problem. The properties of the compensated demand system satisfy the integrability conditions. When consumer demand equations are used, this methodology represents an approximation to the true solution.

The structure of the demand for beef and other fresh meats was represented in the model by deriving an inverse demand system from a distance function similar in form to the cost function used by Deaton and Muelbauer to derive their AIDS model. The compensated system was approximated by holding the quantity index constant. The U.S. was divided into four demand regions and a demand system

estimated for each region. The demand systems contained eight meat commodities: hamburger, roast, steak, pork, whole chicken, chicken parts, other poultry, and other meat. The main component of other poultry is turkey. Household monthly expenditures on each of the eight commodities at the regional level were derived from the BLS' CES from 1982-1986. Price indexes were derived from a separate data set provided by the BLS.

Two major problems were encountered in the integrating of the demand system with the activity analysis model. These were (1) the demand systems did not satisfy the convexity conditions globally and (2) there was a gap between the retail prices being generated by the demand system and the costs of production coming out of the activity analysis model.

This problem was handled by restricting the range in quantity space over which the search for the solution can occur and adjusting the magnitude of the own-quantity parameters in the demand system by a small scaler value.

The gap between the retail price and the costs of production coming from the activity analysis model is known as the marketing margin. The problem of representing the marketing margin was handled by fixing the marketing margin at a fixed level under all scenarios.

The regional activity analysis models of the beef production system were developed from production budgets.

The exception was at the cow-calf stage where market prices for weaned calves and beef culls were used to represent costs of production incurred by producers at this stage. This approach resulted in the size of the breeding herd being fixed.

Four different scenarios to simulate sector responses to various changes in economic environment were run. The first two scenarios looked at the changes which would occur due to increases in the level of poultry consumption. The third scenario examined the impact of increased levels of beef imports on the beef sector and the fourth scenario dealt with changes in sector due to increased levels of beef exports.

In Scenario 1 the level of poultry consumption was increased by the amount which poultry consumption increased from 1982-1987. The increase in poultry consumption caused both retail prices and household consumption to fall, slaughter weight to decline, and the number of cattle finished to decrease in the Southwest and increase in the Plains.

In Scenario 2 the level of poultry consumed was increased by 40%. This reflects the amount by which per capita consumption of poultry increased from 1975-1985. The decline in the consumption of beef in this scenario is approximately one-half of the amount by which the consumption of beef declined during the 1975-1985 time period.

This indicated that the decline in beef per capita consumption of beef during this time period was not completely caused by change in demand but was due to other factors, such as a shift away from beef in consumers' preferences for meat.

In Scenario 3 the level of hamburger imported into the U.S. was increased by 16%, the amount by which beef imports will increase if current trends continue. The increase in beef imports led to a decline in beef production of 1.8%. and a decline in the number of cattle slaughtered of 1.7%. The regional impacts were much greater as beef production declined by 57% in the Southeast and 50% in the West, but actually increased by 4% in the Plains region.

In Scenario 4 the quantity of beef exported was set at a level which reflects a 6% increase in the level of beef exported from present levels of exports. While the increase in beef exports caused U.S. domestic consumption of beef to decline, the production of beef increased by 6%. Thus, whatever losses occurred in production due to a decline in domestic consumption, as a result of a higher domestic price of beef, were offset by the increased export demand. In addition the increase in beef exports caused the size of finished cattle produced to increase, the number of cattle finished in the Plains to decrease and the number of cattle finished to decline in the Southwest.

Conclusions

In conclusion, all of the major objectives of this dissertation were fulfilled. A price endogenous spatial equilibrium model of the U.S. beef sector was successfully operationalized. This involved the development of an activity analysis model of the production system for beef, the derivation of an inverse demand system for meat based on the AIDS model, the estimation of the demand system at the regional level, and the integration of the regional demand systems with the activity analysis model.

The results of the base run of the model conformed with observed phenomena in the beef sector. The level of production and their location are as observed in the beef sector. The exception to this is the lack of utilization of stockering activities. This outcome is believed to be a result of an over-estimation of the costs of finishing stockered cattle. The model was run under four different scenarios and behaved as expected.

The model was solved using GAMS. GAMS facilitated both the formulation of the model and in its documentation. It was especially useful as an aid in representation of the model mathematically. GAMS also facilitated in the development of a portable model. The model is easily solved on a 386 personal computer, taking approximately 20 minutes per run. It also permitted the model to be run at both the University of Florida and at the USDA with little

difficulty. Also, the manner in which GAMS documents the model makes it readily comprehensible to individuals not involved in writing of the program for the model.

With respect to the results from alternative scenarios which are analyzed, several conclusions can be drawn. One conclusion to be drawn from the scenarios is that predicted changes in levels of production are greater in the individual regions and in individual stages of production than the changes occurring in country as a whole. For example, as a result of an increase in the beef imports the level of beef produced in the U.S. declined by 1.8%. However, the production of beef in the Southeast and the West declined by 56.8% and 50%, respectively, with no change occurring in the Midwest or West. The impact of increased beef imports also has varying impacts on producers in the different stages of production. While no change occurred in the number of cattle slaughtered in the Southwest the number of cattle finished in the Southwest declined by 5%. This result occurred despite the fact that U.S. production of finished cattle declined by less than 0.1%. This result demonstrates that by simply looking at aggregate production levels can lead to misleading conclusions concerning the impact of changes in the economic environment on participants in the sector. Adjustments in the sector do not fall evenly across regions.

Another conclusion to be drawn from this research is that the beef industry should concentrate on two things to recapture lost market share. The industry should continue its efforts to change consumers' preferences for beef through introduction of new beef products or advertising. The industry, however, should also concentrate on reducing costs of production. This might be accomplished through technological innovation, such as cattle which are genetically engineered to be more efficient at converting feed to gain or reorganization of structure of sector so that a single operator has control over several stages of production which has occurred in poultry and pork sectors. This two-pronged approach is recommended because the results of the analysis suggest that the reduction in consumption of beef is due to both a change in consumers' preferences for beef and a decline in the relative price of poultry to beef.

This research also indicates that a significant increase in the level of beef exports is another way for the sector to offset decrease in production due to the decline in domestic consumption of beef. However, the ability of the sector to expand exports is contingent on the opening up of markets in Japan and the Europe and on the ability of U.S. producers to compete in these markets with producers from the rest of the world. While there is great potential in the opening up of these markets due to the high standard of living enjoyed by consumers in these countries, the

attitude of consumers towards beef in these countries is likely to be similar to those held by consumers in the U.S. In addition, with the opening up of agricultural markets, producers of beef in the U.S. will not be shielded from competition with producers around the world. These observations suggest that the industry needs concentrate on developing products which satisfy consumers' needs and reducing costs of production in order to realize the potential of the opportunities provided by the opening up of these markets.

Limitations of Model

The analysis conducted by using this model is limited by the fact that the size of the breeding herd is fixed and not endogenously determined. Thus, the sector cannot respond to economic changes by changing the number of calves and culls produced. As a consequence the reaction of the production system to change is not as fluid as it might be. The model is structured so that all the weaned calves produced do not have to be utilized by the production system. Thus, the fixing of the size of the cow herd may be limiting under scenarios in which beef production is expanding. On the other hand, the adjustment of the number cattle pushed through the production system is not the only manner in which the sector has of increasing or decreasing production of beef. It can also increase and decrease production by adjusting the size of the cattle being slaughtered.

Thus, the response of the sector is not completely constrained by fixing the size of the cow herd.

Another limitation of this study is the manner in which the marketing margins are handled. The method used is purely ad hoc and is not consistent with the manner in which the marketing margin is believed to change. In a single commodity market, under the assumption of perfect competition, the marketing margin represents the costs associated in marketing the product. In a multi-commodity framework, however, the marketing margin also includes producer rents in addition to marketing costs. It is the producer rents which increase or decrease in response to changes in market conditions which cause the marketing margin to rise or fall, thereby buffering cattle producers from changes in supply and demand.

This research is also limited by the inability of the demand functions used to satisfy convexity conditions globally. In order to adapt the estimated demand systems for use in the model the commodity space had to be restricted and some of the parameters on the demand functions needed to be adjusted. This is a common problem for all demand systems using flexible functional forms, not just this case in particular. This is because flexible functional forms only have local properties and because convexity is not imposed during estimation.

Areas for Further Research

Since the size of the cattle herd is not endogenously determined in the model one of the first areas of further development of the model would be to make the size of the breeding herd endogenous. It would then be interesting to compare the results obtained with the size of the breeding herd fixed to those obtained when size of the breeding herd can vary.

The results from the import and export scenarios indicate that more effort needs to be placed in incorporating the import and export demand for beef. Currently, the levels of beef imports and exports a fixed at a specified level. In order to gain a better understanding of the industry's competitiveness with producers in other nations the demand for beef imports and exports should be endogenously determined. This could be accomplished by estimating import and export demand functions or by increasing the number of production and demand regions in the model to reflect overseas markets.

Finally, it would be interesting to include a poultry production model with the beef production model. This could be used to analyze the impact on both sectors of changes in the cost of feed and energy as well as technological innovations, such as genetic engineering.

APPENDICES

APPENDIX A

The number of households sampled in one month represents one-third of the total population and the number sampled in one quarter represents the total population. The formula used calculate regional household expenditures is

$$AE(s,m,t) = 3*Days(t)/7*\sum_j W(j,s,t)*E(j,s,m,t)/3*\sum_j W(j,s,t)$$

where AE(s,m,1,1) represents the expenditure per household in region s on commodity m in month t; W(j,s,t) is the sample weight attached to the household j in region s in month t; and E(j,s,m,t,1) represents the expenditure of household j in region s on food item m in month t. Days(t)/7 converts weekly expenditure to monthly expenditure. Multiplying weighted expenditures for one month by 3 gives a representation for the total population. $3*\sum W(j,s,t)$ represents the amount of observations for the total population. If the decision-making process used to define the choice set does not reflect the consumer's decision making process then the choice set is not properly defined and the demand system does not represent consumer's preferences appropriately.

For the formulas used to compute the missing prices see Table A.1.

Table A.1. FORMULAS USED TO COMPUTE IMPUTED PRICES

Factor	Commodities
	Poultry
USA	$P_w = .00939 + .36489\ P_{leg} + .229935\ P_{breast}$
South	$P_w = .004496 + .459131\ P_{leg} + .134901\ P_{breast}$
West	$P_w = .00357 + .349183\ P_{leg} + .231541\ P_{breast}$
Midwest	$P_{legs} = .915635 + .055394\ P_w + .258423\ P_{breast}$
	Beef
Steak	$P_w = 2.171608 + .457926\ P_{usa} - .02892\ P_{ne} + .730283\ P_{mw} - .87934\ P_{south}$
Ground beef	$P_{usa} = -.2464 + 7.1493\ P_{ne} - 2.68675\ P_{mw} - 1.68078\ P_{south} - 1.62809\ P_{west}$
Roast	$P_{usa} = -.01535 + .216136\ P_{ne} - .369562\ P_{mw} - .281286\ P_{south} - 1.62809\ P_{west}$
	Pork
Ham	$P_{usa} = .298427\ P_{ne} - .255562\ P_{mw} - .31477\ P_{south} - .127058\ P_{west}$

APPENDIX B

TABLE B.1. NUMBER OF CATTLE BY REGION, 1984-1988.

Region	Year	Beef Cows	Milk Cows	Total	Percent Beef of Total	Region Percent of U.S. Total
		000				
Northeast	1984	360	2,114	2,473	14.5	1.0
	1985	339	2,096	2,434	13.9	1.0
	1986	335	2,128	2,463	13.6	1.0
	1987	374	2,009	2,383	15.7	1.1
	1988	369	1,921	2,290	16.1	1.1
	Avg.	355	2,054	2,409	14.8	1.0
Southeast	1984	6,733	2,436	9,169	72.3	18.0
	1985	7,371	1,347	8,718	84.5	20.8
	1986	7,076	1,380	8,456	83.7	21.0
	1987	7,278	1,281	8,559	85.0	21.5
	1988	6,968	1,248	8,216	84.8	21.1
	Avg.	7,085	1,538	8,624	82.3	20.5
Southwest	1984	9,789	621	10,410	94.0	26.1
	1985	9,163	595	9,758	93.9	25.9
	1986	9,057	873	9,930	91.2	26.9
	1987	8,773	586	9,359	93.7	26.0
	1988	8,662	607	9,269	93.5	26.3
	Avg.	9,089	656	9,745	93.3	26.2
Midwest	1984	12,167	5,113	17,280	70.4	32.5
	1985	11,465	4,962	16,427	69.8	32.4
	1986	10,925	5,140	16,065	68.0	32.5
	1987	10,761	4,814	15,575	69.1	31.9
	1988	10,548	4,699	15,247	69.2	32.0
	Avg.	11,173	4,946	16,119	69.3	32.2

TABLE B.1.--Continued

Region	Year	Beef Cows	Milk Cows	Total	Region Percent Beef of Total	Percent of U.S. Total
		000				
Plains	1984	5,334	535	5,869	90.9	14.2
	1985	4,914	525	5,439	90.3	13.9
	1986	5,334	541	5,875	90.8	15.9
	1987	4,606	515	5,121	89.9	13.6
	1988	4,544	508	5,052	89.9	13.8
West	1984	2,237	1,290	3,527	63.4	6.0
	1985	2,134	1,294	3,428	62.2	6.0
	1986	2,039	1,368	3,407	59.8	6.1
	1987	1,988	1,297	3,285	60.5	5.9
	1988	1,877	1,324	3,201	58.6	5.7
	Avg.	2,055	1,315	3,370	60.9	5.9
U.S.	1984	37,494	11,109	48,603	77.1	100.0
	1985	35,370	10,805	46,175	76.6	100.0
	1986	33,633	11,177	44,810	75.1	100.0
	1987	33,779	10,502	44,281	76.3	100.0
	1988	32,958	10,307	43,265	76.2	100.0
	Avg.	34,647	10,780	45,427	76.3	100.0

Source: USDA (1989).

TABLE B.2 COST OF PRODUCING CULLS AND CALVES.

Region	Calves	Culls
	$/cwt	
Southeast	59.32	39.65
Midwest	65.29	44.34
Southwest	63.34	42.68
West	58.64	43.27
Plains	65.38	42.34

Source: USDA (1989).

TABLE B.3 COSTS INCURRED AT THE STOCKERING STAGE.

Region	Type Cost	Year-lings	1 1/2 years
		——————$/head——————	
Southeast	Variable	70.99	166.76
	Fixed	15.80	35.10
Midwest	Variable	69.74	163.86
	Fixed	19.84	49.60
Southwest	Variable	71.73	168.51
	Fixed	14.76	36.91
West	Variable	72.01	169.24
	Fixed	20.03	60.08
Plains	Variable	70.80	166.41
	Fixed	16.88	42.18

Source: Disney (1989).

Formulas used to calculate the average cost (AC) of stockering activities on a per head basis are shown below.

Southeast: AC = 1.050 (Variable + Fixed)
Midwest: AC = 1.046 (Variable + Fixed)
Southwest: AC = 1.050 (Variable + Fixed)
West: AC = 1.197 (Variable + Fixed)
Plains: AC = 1.197 (Variable + Fixed)

TABLE B.4. COST OF PRODUCTION ACTIVITIES AT THE FINISHING STAGE.

Region	Type of Cost	Fed				Nonfed	
		Calf to 900 lbs	Calf to 1,100 lbs	Yearling to 1,200 lbs	1 1/2 year to 1,300 lbs	Yearling to 900 lbs	1 1/2 year to 1,100 lbs
Southeast	Variable	277.98	424.43	452.49	472.40	205.50	263.89
	Fixed	29.44	42.79	35.75	28.90	16.20	16.26
	Corn	46.00	70.20	69.20	63.30	31.40	37.10
Midwest	Variable	364.96	404.55	434.19	454.19	197.16	253.58
	Fixed	27.76	40.37	33.72	25.25	15.36	15.35
	Corn	46.00	70.20	69.20	63.30	31.40	37.10
Southwest	Variable	262.56	402.55	426.45	443.04	193.66	249.70
	Fixed	19.18	27.86	23.27	18.81	10.55	17.72
	Corn	46.00	70.20	69.20	63.30	31.40	37.10
West	Variable	306.54	468.43	482.55	520.00	220.43	290.48
	Fixed	20.02	29.07	24.30	19.62	10.77	10.81
	Corn	46.00	70.20	69.20	63.30	31.40	37.10
Plains	Variable	222.20	398.43	425.66	454.64	193.30	253.27
	Fixed	19.60	18.46	23.78	19.21	11.00	11.04
	Corn	46.00	70.20	69.20	63.30	31.40	37.10

Source: Disney (1989).

Formulas used to calculate the average cost (AC) of finishing activities from Table B.4 are shown below.

Southeast: AC=0.875*Variable+Fixed+0.16*Corn
Midwest: AC=0/875*Variable+Fixed+0.05*Corn
Southwest: AC=0.875*Variable+Fixed+0.11*Corn
West: AC=0.875*Variable+Fixed+0.11*Corn
Plains: AC=0.875*Variable+Fixed+0.05*Corn

TABLE B.5 CARCASS YIELD FROM LIVE ANIMAL.

Item	Yield
900 lbs	.59
1,100 lbs	.61
1,200 lbs	.62
1,300 lbs	.63
Yearling	.52
1 1/2 year old	.54
Cull	.50

TABLE B.6 PRIMAL CUT YIELD FROM CARCASS.

Item	Fed	Nonfed	Cull
Roast	.227	.209	.091
Steak	.274	.251	.109
Lean trim	.101	.220	.530
Medium trim	.111	.120	.030
Fat and bone	.287	.200	.240

TABLE B.7. PARAMETER ESTIMATES ON TRANSLOG COST FUNCTION FOR SLAUGHTERING AND FABRICATING.

Item	a	b	c
Parameter	7.3165	0.4801	0.0409
Standard Error	0.1918	0.0480	0.0059
T-Statistic	38.1500	9.9970	6.9231
R^2	0.9980		

The equation estimated is:

$$\ln(TC) = a + b*\ln(q) + 1/2*c*(\ln(q)^2) + e$$

where TC is the total cost of slaughtering the live animal and fabricating into primal cuts and q equals the quantity of cattle slaughtered per week.

The formula used to calculate the average cost (AC) of slaughtering and fabricating is

$$AC = (\exp(7.32 + 0.48*\ln(Q/52) + 0.02*(\ln(Q)^2))/Q$$

where AC is the average cost and Q is the slaughter plants annual capacity.

TABLE B.8. DISTANCE BETWEEN SUPPLY REGIONS

Region	South-west	Mid-west	South-west	West	Plains
	(miles)				
Southeast	50	1090	986	-	-
Midwest	1090	50	830	-	425
Southwest	986	830	100	1352	600
West	-	-	1352	100	1150
Plains	-	425	600	1150	100

Source: Kennedy (1982); Disney (1989).

The cost of transporting live cattle were determined by using the equations listed below.

For routes less than 1,000 miles:

$/cwt = 0.121*(0.7132 + 0.00181(miles))

$/head = ($/cwt) (cwt/head)

For routes greater than 1,000 miles:

$/cwt = 0.121*(0.7132 + 0.00165(miles))

$/head = ($/cwt) (cwt/head)

TABLE B.9. DISTANCES BETWEEN SUPPLY AND DEMAND REGIONS

Supply Center	Demand Center	Miles
West: Stockton, CA	West: San Francisco, CA -Denver, CO	363.75
	South: Dallas, TX - Atlanta, GA	2,237.80
Plains: Sterling, CO	West: San Francisco, CA -Denver, CO	864.75
	South: Dallas, TX - Atlanta, GA	1,342.40
	Midwest: Chicago, IL	871.00
	Northeast: New York, NY	1,646.00
Southwest: Lubbock, TX	West: San Francisco, CA -Denver, CO	1,209.75
	South: Dallas, TX -Atlanta, GA	552.84
	Midwest: Chicago, IL	1,134.00
	Northeast: New York, NY	1,795.00
Midwest: Sioux City, IA	West: San Francisco, CA -Denver, CO	1,288.75
	South: Dallas, TX -Atlanta, GA	974.56
	Midwest: Chicago, IL	1,300.00
	Northeast: New York, NY	1,446.00
Southeast: Montgomery, AL	South: Dallas, TX -Atlanta, GA	1,007.00
	Northeast: New York, NY	306.60

Source: Kennedy (1982).

The distances for the West and South demand regions represent the weighted average of the distance between the supply center and the individual cities. The weights used are the demand region's population accounted for by the sub-region for which the individual city acts as the demand center.

Transportation costs were calculated using the following formula:

$$\$/cwt = 0.7589 + 0.00258(miles) - (3.35 \times 10^{7})\ (miles)^{2}$$

Source: Ward and Farris.

APPENDIX C
GAMS PROGRAM

```
$OFFSYMLIST OFFSYMXREF
$title   US BEEF MODEL
*############  MESSAGES  ##############################################
$ontext
    ATTENTION: THIS NEEDS TO BE GIVEN STARTING VALUES
               AND BOUNDS ON VARIABLES BEFORE RUNNING.

     --Dairy culls from the northeast have been included in the
       midwest region.
     --The values of the own quantity parameters on the regional demand
       have been adjusted by +.0025 (+.0001 in the West) to permit the equations
       to be negative semi-definite over the range of quantities permitted.
     --The quantites of exogenous meat products consumed have been placed at
       the minimum value observed over the data set.

$offtext
*#################################################################
*######      DIMENSIONS OF SUPPLY VARIABLES USED IN MODEL     ########
*#################################################################

SETS  U0  CLASS OF COW SUPPLIED
          / FB9, FB11, FB12, FB13, NFB1, NFB1-5, Cull/
      U1  CLASSES SLAUGHTERED CARCASSES
          / FB9, FB11, FB12, FB13, NFB1, NFB1-5, Cull/
      U2  TYPES OF FABRICATED CUTS
          /ROAST, STEAK, LNTRM, MDTRM, F-T/
      K1  PRODUCTION PROCESSES AT SLAUGHTER PLANT
          / FB9, FB11, FB12, FB13, NFB1, NFB1-5, Cull/
      K2  PRODUCTION PROCESSES AT FABRICATION STAGE
          / FB9, FB11, FB12, FB13, NFB1, NFB1-5, Cull/
      L   SLAUGHTER PLANTS
          /PL1*PL5/
      EXX  FOREIGN DEMAND REGIONS
          /EXX1*EXX5 /
      SR  DOMESTIC SUPPLY REGIONS
          /SE, MW, SW, W, PL/
      SRD SUPPLY REGIONS FOR DAIRY HERD CULLS
          /NNE,SE,SW,MW,W,PL/
      IM  FORGEIN SUPPLY REGIONS
          /IMPORTS/
      H   HAMBURGER ROWS
          /Min  MINIMUM FAT CONTENT
           Max  MAXIMUM FAT CONTENT/


     SRL(SR,L) NO. OF PLANTS IN EACH REGION
     /    SE.PL1
          MW.(PL1*PL5)
          SW.(PL1*PL5)
          W.PL1
          PL.(PL1*PL3)  /

     PC(U0,K1)  PRODUCTION COMBINATIONS
          /FB9.FB9
           FB11.FB11
           FB12.FB12
           FB13.FB13
           NFB1.NFB1
           NFB1-5.NFB1-5
           Cull.Cull /
$lines 11
SRLPC(SR,L,U0,K1)  SRL U PC
/SE.PL1       .(FB9.FB9,FB11.FB11,FB12.FB12,FB13.FB13,
                NFB1.NFB1,NFB1-5.NFB1-5,Cull.Cull)
 MW.(PL1*PL5).(FB9.FB9,FB11.FB11,FB12.FB12,FB13.FB13,
                NFB1.NFB1,NFB1-5.NFB1-5,Cull.Cull)
 SW.(PL1*PL5).(FB9.FB9,FB11.FB11,FB12.FB12,FB13.FB13,
                NFB1.NFB1,NFB1-5.NFB1-5,Cull.Cull)
 W .PL1       .(FB9.FB9,FB11.FB11,FB12.FB12,FB13.FB13,
                NFB1.NFB1,NFB1-5.NFB1-5,Cull.Cull)
 PL.(PL1*PL3).(FB9.FB9,FB11.FB11,FB12.FB12,FB13.FB13,
                NFB1.NFB1,NFB1-5.NFB1-5,Cull.Cull)    /

RTL(SR,L,U2) PRIMAL CUTS TO BE SENT TO RETAIL OR TO MAKE HAMBURGER
     /SE.PL1.(ROAST,STEAK)
      MW.(PL1*PL5).(ROAST,STEAK)
      SW.(PL1*PL5).(ROAST,STEAK)
      W .PL1.(ROAST,STEAK)
      PL.(PL1*PL3) .(ROAST,STEAK)                    /
```

```
HB(U2) PRIMAL CUTS USED TO MAKE HAMBURGER
     /ROAST,STEAK,MDTRM,LNTRM                              /

SRLHB(SR,L,U2)  SRL U PRIMAL CUTS USED TO MAKE HAMBURGER

/SE.PL1.(ROAST,STEAK,MDTRM,LNTRM)
 MW.(PL1*PL5).(ROAST,STEAK,MDTRM,LNTRM)
 SW.(PL1*PL5).(ROAST,STEAK,MDTRM,LNTRM)
 W .PL1.(ROAST,STEAK,MDTRM,LNTRM)
 PL.(PL1*PL3) .(ROAST,STEAK,MDTRM,LNTRM)              /


ALIAS(U0,V0)
ALIAS(SR,SRR)

*######   LIVE ANIMAL VARIABLE DIMENSIONS                ###################

  SETS     U5  CLASS OF ANIMAL COMING FROM DAIRY
                /CULL                                    /
           U6  CLASS OF ANIMAL PRODUCED AT COW-CALF STAGE
                / CALF, CULL                             /
           U7  CLASS OF ANIMAL PRODUCED AT STOCKER STAGE
                / NFB1, NFB1-5                           /
           U8  CLASS OF ANIMAL PLACED ON FEEDLOT
                / CALF, NFB1, NFB1-5                     /
           U9  CLASS OF ANIMAL PRODUCED ON FEEDLOT
                / FB9, FB11*FB13                         /
           U10  CLASS OF ANIMAL USED AT SLAUGHTER PLANT
                / FB9, FB11*FB13, NFB1, NFB5, CULL /
           K6  PRODUCTION PROCESSES AT COW-CALF STAGE        COW-CALF
                / BREED                                  /
           K7  PRODUCTION PROCESSES AT STOCKER STAGE         STOCKER
                / NFB1, NFB1-5                           /
           K8  PRODUCTION PROCESSES AT FINISHING STAGE       FEEDLOT
                / FB9, FB11*FB13, NFB1-FB9, NFB2-FB11 /

           PC7(U7,K7)  NONFED PRODUCTION COMBINATIONS
                / NFB1.NFB1, NFB1-5.NFB1-5               /
           PC8(U8,K8)  PRODUCTION COMBINATIONS
                / CALF.(FB9,FB11)
                  NFB1.(NFB1-FB9,FB12)
                  NFB1-5.(NFB2-FB11,FB13)                /
           PC88(U9,K8)  PRODUCTION COMBINATIONS
                  /FB9.(FB9,NFB1-FB9)
                   FB11.(FB11,NFB2-FB11)
                   FB12.FB12
                   FB13.FB13                             /

           I   TYPES OF PRODUCTION COSTS
                 /VAR, FIXED, CORN                       /

         DSRL(SRR,SR,L)  SUPPLY REGION AND PLANT COMBINATIONS
                 /(SE,MW,SW)      .SE.PL1
                  (SE,MW,SW,PL)   .MW.(PL1*PL5)
                  (SE,MW,SW,PL,W).SW.(PL1*PL5)
                  (SW,PL,W)       .W.PL1
                  (MW,SW,PL,W)    .PL.(PL1*PL3)  /

         DSRLD(SRD,SR,L)  DAIRY SUPPLY AND PLANT COMBINATIONS
                 /(SE,MW,SW)      .SE.PL1
                  (SE,MW,SW,PL)   .MW.(PL1*PL5)
                  (SE,MW,SW,PL,W).SW.(PL1*PL5)
                  (SW,PL,W)       .W.PL1
                  (MW,SW,PL,W)    .PL.(PL1*PL3)  /

ALIAS(U6,V6)

$eject
*#########################################################################
*#######              SUPPLY PARAMETERS                                  #####
*####### The data in this section is organized according to            #####
*####### the production stages found in the beef sector.  It           #####
*####### starts  with the cow-calf stage then the stocker stage,       #####
*####### the finishing stage, and finally the slaughter/processing     #####
*####### stage.  For the most part the quantity parameters are         #####
*####### first then the cost parameters.                               #####
*#########################################################################
PARAMETER  DAIRY(SRD,U5)  SUPPLY OF DAIRY CALLS BY REGION (THSND HD)
               /SE.CULL       331200
                MW.CULL      2332600
                SW.CULL       200300
                 W.CULL       608400
                PL.CULL       122900 /
*NNE.CULL      772.0
PARAMETER  CSTDA(SRD,U5)  COST OF DAIRY CULLS BY SUPPLY REGION (DOL PER CWT)
               /SE.CULL     39.65
                MW.CULL     44.34
                SW.CULL     42.68
```

```
                W.CULL      42.34
               PL.CULL      43.27 /
*NNE.(SE,MW,SW,W,PL).CULL    40.27
PARAMETER  DARYWT(SRD,U5)  AVERAGE WEIGHT DAIRY CULL BY REGION (CWT)
              /SE.CULL      8.75
               MW.CULL      9.42
               SW.CULL      9.00
                W.CULL      9.57
               PL.CULL      9.68 /
*NNE.CULL     9.50
PARAMETER RD(SRD,U5) COST OF DAIRY CULLS TO SLAUGHTER (DOL PER HD);
         RD(SRD,U5)=DARYWT(SRD,U5)*CSTDA(SRD,U5);
DISPLAY RD;

*#############                                                  ###############
*#############              COW-CALF STAGE                      ###############
*#############                                                  ###############
PARAMETER  Z5(SR,K6)  COWS &HEIFERS THAT HAVE CALVED BY REGION (HD)
          /SE.BREED     7.0852E+06
          MW.BREED     11.1732E+06
          SW.BREED     9.0888E+06
           W.BREED     2.05474E+06
          PL.BREED     4.9464E+06    /
PARAMETER C6(SR,K6)  BREEDING STOCK PER UNIT OF COW-CALF PROCESS (HD)
          / (SE,MW,SW,W,PL).BREED       1 /

TABLE D6(SR,U6,K6) CULLS & CALVES PER UNIT OF COW-CALF PROCESS (HD)
          CALF.BREED      CULL.BREED
     SE         .59             .10
     MW         .61             .14
     SW         .63             .12
      W         .57             .17
     PL         .62             .16
Parameter cd6(sr,k6)  sum culls and calves available in region;
          cd6(sr,k6)=sum(u6, z5(sr,k6)*d6(sr,u6,k6))/7;
Display cd6;
TABLE  DC(SR,U6)  THE WEIGHT COMING FROM COW-CALF STAGE (CWT PER HEAD)
               CALF          CULL
    SE         4.33          8.75
    MW         4.65          9.42
    SW         3.90          9.00
     W         4.15          9.57
    PL         4.30          9.68

TABLE R6A(SR,U6) COST OF PRODUCING CULLS  AND CALVES (DOLLARS PER CWT)
               CALF          CULL
    SE        59.32         39.65
    MW        65.29         44.34
    SW        63.34         42.68
     W        58.64         43.27
    PL        65.38         42.34

PARAMETER R6(SR,U6)  COST COW-CALF STAGE (DOLLARS PER HD);
               R6(SR,U6)=R6A(SR,U6)*DC(SR,U6);
DISPLAY R6;
$eject
*#############                                                  ###############
*###########                  THE STOCKER STAGE                   #############
*#############                                                  ###############

PARAMETER C7(SR,U6,K7)   CALVES USED PER UNIT STOCKERING PROCESS (HD)
         /(SE,MW,SW,W,PL).CALF.(NFB1,NFB1-5)      1 /
display c7;
PARAMETER D7(SR,U7,K7)  NFB & NFB1-5 PRODUCED PER UNIT STOCKERING PROCESS (HD);
          D7(SR,U7,K7)=1 $PC7(U7,K7);
DISPLAY D7;
TABLE  DS(SR,U7)  THE WEIGHT COMING FROM STOCKER STAGE (CWT PER HEAD)
               NFB1          NFB1-5
    SE         6.48           8.58
    MW         6.80           8.90
    SW         6.05           8.15
     W         6.30           8.40
    PL         6.45           8.55


TABLE   R7A(SR,I,K7) COST DATA FOR STOCKER STAGE (DOLLARS PER HEAD)
                          NFB1         NFB1-5
   SE.VAR                 70.99        166.76
   SE.FIXED               15.80         35.10
   MW.VAR                 69.74        163.86
   MW.FIXED               19.84         49.60
   SW.VAR                 71.73        168.51
   SW.FIXED               14.76         36.91
    W.VAR                 72.01        169.24
    W.FIXED               20.03         60.08
   PL.VAR                 70.80        166.41
   PL.FIXED               16.88         42.18
```

```
PARAMETER R7(SR,K7) COST  FORAGE FED STOCKER (DOLLARS PER HD);
                R7('SE',K7)= 1.05* SUM(I, R7A('SE',I,K7));
                R7('MW',K7)= 1.046*SUM(I, R7A('MW',I,K7));
                R7('SW',K7)=  1.05* SUM(I, R7A('SW',I,K7));
                R7('W', K7)= 1.197*SUM(I, R7A('W' ,I,K7));
                R7('PL',K7)= 1.197*SUM(I, R7A('PL',I,K7));
DISPLAY R7;
$eject
*###################                                          ##################

*################                THE FINISHING STAGE                 #############
*###################                                                  ##################
TABLE  DAA(SR,U9)  THE WEIGHT LEAVING THE FEEDLOT (CWT PER HEAD)
          FB9     FB11    FB12    FB13
   SE     8.98    10.98   11.98   12.98
   MW     9.30    11.30   12.30   13.30
   SW     8.55    10.55   11.50   12.55
    W     8.80    10.80   11.60   12.80
   PL     8.95    10.95   11.95   12.95


PARAMETER C8(SR,U8,K8) CALF,NFB &NFB1-5 USED PER UNIT FINISHING PROCESS (HD);
        C8(SR,U8,K8)=1 $PC8(U8,K8);
DISPLAY C8;
PARAMETER D8(SR,U9,K8) FINISHED CATTLE PER UNIT OF FINISHING PROCESS (HD);
        D8(SR,U9,K8)=1 $PC88(U9,K8);
DISPLAY D8;
TABLE   R8A(SR,I,K8) COST DATA FOR FINISHING IN A FEEDLOT (DOLLARS PER HEAD)
                        FB9         FB11        FB12        FB13
   SE.VAR               277.98      424.43      452.49      472.40
   SE.FIXED              29.44       42.79       35.75       28.90
   SE.CORN               46          70.2        69.2        63.3

   MW.VAR               264.96      404.55      434.19      454.19
   MW.FIXED              27.76       40.37       33.72       25.25
   MW.CORN               46          70.2        69.2        63.3

   SW.VAR               262.56      402.55      426.45      443.04
   SW.FIXED              19.18       27.86       23.27       18.81
   SW.CORN               46          70.2        69.2        63.3

    W.VAR               306.54      468.43      482.55      520.00
    W.FIXED              20.02       29.07       24.3        19.62
    W.CORN               46          70.2        69.2        63.3

   PL.VAR               222.20      398.43      425.66      454.64
   PL.FIXED              19.6        28.46       23.78       19.21
   PL.CORN               46.00       70.20       69.20       63.30

+
                        NFB1-FB9    NFB2-FB11
   SE.VAR               205.50      263.89
   SE.FIXED              16.2        16.26
   SE.CORN               31.4        37.10

   MW.VAR               197.17      253.58
   MW.FIXED              15.36       15.35
   MW.CORN               31.4        37.1

   SW.VAR               193.66      249.70
   SW.FIXED              10.55       17.72
   SW.CORN               31.4        37.1
    W.VAR               220.43      290.48
    W.FIXED              10.77       10.81
    W.CORN               31.4        37.1
   PL.VAR               193.30      253.27
   PL.FIXED              11.0        11.04
   PL.CORN               31.4        37.1

PARAMETER R8(SR,K8) COST  FINISHING IN A FEEDLOT (DOLLARS PER HD);
             R8('SE',K8)=0.875*(R8A('SE','VAR',K8)
                        +R8A('SE','FIXED',K8))
                        +0.16*(R8A('SE','CORN',K8));
             R8('MW',K8)=0.875*(R8A('MW','VAR',K8)
                        +R8A('MW','FIXED',K8))
                        +0.05*(R8A('MW','CORN',K8));
             R8('SW',K8)=0.875*(R8A('SW','VAR',K8)
                        +R8A('SW','FIXED',K8))
                        +0.11*(R8A('SW','CORN',K8));
             R8('W',K8)=0.875*(R8A('W','VAR',K8)
                        +R8A('W','FIXED',K8))
                        +0.11*(R8A('W','CORN',K8));
             R8('PL',K8)=0.875*(R8A('PL','VAR',K8)
                       +R8A('PL','FIXED',K8))
                       +0.05*(R8A('PL','CORN',K8));
```

```
DISPLAY R8;
$eject
*################
*############          SLAUGHTER & PROCESSING STAGE          ################
*################                                                ############
                                                                ################

PARAMETER  C1(SR,L,UO,K1) TYPE OF CARCASS USED IN KILL-CHILL (HEAD);
       C1(SR,L,UO,K1)=1 $SRLPC(SR,L,UO,K1);

DISPLAY C1;
PARAMETER  D1A(SR,L,UO,K1)  OUTPUT FROM  KILL-CHILL (HEAD);
       D1A(SR,L,UO,K1)=1 $SRLPC(SR,L,UO,K1);
display d1a;
PARAMETER   CAPCTY(SR,L)  NO. AND SIZE OF SLAUGHTER PLANTS BY REGION (HD)
               /SE.p11              125000
                MW.p11              250000
                MW.p12              500000
                MW.p13              750000
                MW.p14             1000000
                MW.p15             1300000
                SW.p11              250000
                SW.p12              500000
                SW.p13              750000
                SW.p14             1000000
                SW.p15             1300000
                 W.p11              125000
                PL.PL1              250000
                PL.p12              500000
                PL.PL3             1000000   /

PARAMETER   TCAPCTY(SR,L)   TOTAL SLAUGHTER CAPACITY BY REGION (HD)
              /SE.p11              1750000
                MW.p11             1250000
                MW.p12             7000000
                MW.p13             4500000
                MW.p14             2000000
                MW.p15             3900000
                SW.p11             1750000
                SW.p12              500000
                SW.p13             1500000
                SW.p14             1000000
                SW.p15             1300000
                 W.p11             2250000
                PL.PL1              250000
                PL.p12             3000000
                PL.PL3             1300000   /

PARAMETER C10(SR,K1) THE WEIGHT ENTERING THE MEATPACKING PLANT;
         C10(SR,'FB9')=DAA(SR,'FB9');
         C10(SR,'FB11')=DAA(SR,'FB11');
         C10(SR,'FB12')=DAA(SR,'FB12');
         C10(SR,'FB13')=DAA(SR,'FB13');
         C10(SR,'NFB1')=DS(SR,'NFB1');
         C10(SR,'NFB1-5')=DS(SR,'NFB1-5');
         C10(SR,'CULL')=DC(SR,'CULL');
DISPLAY C10;

TABLE  DA(SR,K1)  THE WEIGHT COMING FROM FINISHING STAGE (CWT PER HEAD)
          FB9    FB11   FB12   FB13   NFB1  NFB1-5   CULL
    SE    8.98   10.98  11.98  12.98  6.48   8.58    8.75
    MW    9.30   11.30  12.30  13.30  6.80   8.90    9.42
    SW    8.55   10.55  11.50  12.55  6.05   8.15    9.00
     W    8.80   10.80  11.60  12.80  6.30   8.40    9.57
    PL    8.95   10.95  11.95  12.95  6.45   8.55    9.68

PARAMETER  KILL(K1)  carcass yield from live animal (percentage)
       /  FB9      .59
          FB11     .61
          FB12     .62
          FB13     .63
          NFB1     .52
          NFB1-5   .54
          Cull     .50  /

PARAMETER D1(SR,K1)  THE CARCAS WGHT (CWT PER HEAD);
     D1(SR,K1)= KILL(K1)*DA(SR,K1);
DISPLAY D1;

TABLE  CUTOUT(U2,K1)  primal cuts percentage of carcass
       (FB9,FB11,FB12,FB13)          (NFB1,NFB1-5)  Cull
ROAST          .227                      .209        .091
STEAK          .274                      .251        .109
LNTRM          .101                      .22         .53
MDTRM          .111                      .12         .03
F-T            .287                      .2          .24
```

```
PARAMETER   D2(SR,U2,K1)     WEIGHT OF FABRICATED CUTS (CWT);
     D2(SR,U2,K1)=CUTOUT(U2,K1)*D1(SR,K1);
DISPLAY D2;

PARAMETER C2(SR,L,U0,K1) CARCASS USED PER UNIT FABRICATION (HEAD);
          C2(SR,L,U0,K1)=1 $SRLPC(SR,L,U0,K1);
display c2;
PARAMETER     A3(SR,H,U2) FAT CONTENT OF PRIMAL CUTS;
     A3(SR,'MIN','ROAST')=  -.20;
     A3(SR,'MAX','ROAST')=   .20;
     A3(SR,'MIN','STEAK')=  -.20;
     A3(SR,'MAX','STEAK')=   .20;
     A3(SR,'MIN','LNTRM')=  -.15;
     A3(SR,'MAX','LNTRM')=   .15;
     A3(SR,'MIN','MDTRM')=  -.50;
     A3(SR,'MAX','MDTRM')=   .50;

PARAMETER C3(SR,U2)  LEVEL USED IN HAMBURGER MANUFACTURE (CWT);
     C3(SR,U2)=1 $HB(U2);
display c3;
PARAMETER  PAT(SR,H)  PERCENT FAT REQUIREMENT OF HAMBURGER;
               PAT(SR,'MIN')=-.15 ;
               PAT(SR,'MAX')= .27 ;
*DISPLAY PAT;


*#####                          ###################################
*#####   COSTS OF PRODUCTION    ###################################


PARAMETER      SINT(SR,L) Intercept on cost function for slaughter;

                    SINT(SR,L)= 7.32          $SRL(SR,L);

PARAMETER      SB1(SR,L) linear term coefficent on cost function;
                    SB1(SR,L)= .48            $SRL(SR,L);

PARAMETER      SC1(SR,L) Quadratic term coefficient on cost function;
                   SC1(SR,L)=.02              $SRL(SR,L);

PARAMETER R1(SR,L)  AVERAGE COST OF SLAUGHTERING LIVE ANIMAL (DOLLARS PER HD);
    R1(SR,L)=((EXP(SINT(SR,L)
            +SB1(SR,L)*LOG(capcty(SR,L)/52)
            +(SC1(SR,L))*SQR(LOG(capcty(SR,L)/52))))/(capcty(SR,L)/52))
            $SRL(SR,L);
DISPLAY R1;

PARAMETER   R3(SR,L)  COST OF MAKING HAMBURGER  (DOL PER CWT);
            R3(SR,L)=.234*R1(SR,L)/(sum(k1, kill(k1)*da(sr,k1))/7);
DISPLAY R3;
$eject
*#####################################################################
*########                  THE DEMAND PARAMETERS              ########
*######## This section contains the parameters for the demand ########
*######## equations for the domestic markets and the price    ########
*######## received by domestic producers in foreign markets. ########
*#####################################################################

SETS  U3  TYPES OF PROCESSED CUTS
          /HMBRGR, ROAST, STEAK/
      U4  OTHER MEAT CONSUMED BY HOUSEHOLD (EXOGENOUS)
          /PORK, OTHMEAT, CHICKENW, CHICKENP, OTHPOULT/
      DR  DOMESTIC DEMAND REGIONS
          /NNE, S, MW, W /

     IMPRTS(U3) TABLE CUTS IMPORTED
               /HMBRGR/

     IMPRTDMND(IM,DR,U3) THE DEMAND MARKETS TO WHICH IMPORTS ARE SHIPPED
               /IMPORTS.(S,W).HMBRGR    /

ALIAS(U3,V3)


TABLE  BBFIMPRT(IM,U3)  BASE LEVEL BEEF AVAILABLE FROM IMPORT REGIONS (CWT)
               HMBRGR          ROAST          STEAK
     IMPORTS   14.4634E+06
PARAMETER BFIMPRT(IM,U3) BEEF AVAILABLE FROM IMPORT REGIONS (CWT);
        BFIMPRT(IM,U3)=1*BBFIMPRT(IM,U3);
PARAMETER     RF(IM,U3) COST OF FOREIN BEEF (DOL PER CWT)
    / IMPORTS.HMBRGR   90.2 /
```

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TABLE  BII(U3,DR)   THE MATRIX OF OWN-QUANTITY EFFECTS
                NNE          S          MW          W
HMBRGR        .13946     .13608     .15571     .13521
ROAST         .084251    .082355    .080141    .044852
STEAK         .12838     .12413     .12447     .136

TABLE   BIJ(U3,V3,DR)  THE MATRIX OF CROSS-QUANTITY EFFECTS
                   NNE        S          MW          W
HMBRGR.ROAST     -.01365   -.01556    -.01716    -.00189
ROAST.STEAK      -.02393   -.01110    -.01699    -.00681
STEAK.HMBRGR     -.01644   -.02965    -.02902    -.03135

TABLE  CIJ(U3,U4,DR) THE MATRIX OF FIXED CROSS-QUANTITY EFFECTS
          PORK.NNE  OTHMEAT.NNE  CHICKENW.NNE CHICKENP.NNE OTHPOULT.NNE
HMBRGR     -.04072     -.02928      -.00934     -.02118     -.00633
ROAST      -.02033     -.01288      -.00471     -.00251     -.00373
STEAK      -.03357     -.02066      -.00866     -.01462     -.00798

+          PORK.S    OTHMEAT.S   CHICKENW.S   CHICKENP.S   OTHPOULT.S
HMBRGR     -.04121     -.02983      -.00667     -.00562     -.00505
ROAST      -.02122     -.01529      -.00990     -.00312     -.00365
STEAK      -.03297     -.02618      -.00310     -.01681     -.00182

+          PORK.MW   OTHMEAT.MW  CHICKENW.MW  CHICKENP.MW  OTHPOULT.MW
HMBRGR     -.05532     -.02727      -.00840     -.01176     -.00429
ROAST      -.02047     -.00897      -.00655     -.00598     -.00150
STEAK      -.03283     -.02328      -.00564     -.01066     -.00354

+          PORK.W    OTHMEAT.W   CHICKENW.W   CHICKENP.W   OTHPOULT.W
HMBRGR     -.04208     -.03337      -.00754     -.01237     -.00647
ROAST      -.01752     -.00952      -.00101     -.00485     -.00312
STEAK      -.04588     -.02180      -.00683     -.01308     -.01011

PARAMETER    A(DR,U3)  VALUES OF INTERCEPTS
                /NNE.HMBRGR     0.10712
                 NNE.ROAST      0.14033
                 NNE.STEAK      0.21690
                 S.HMBRGR       0.12131
                 S.ROAST        0.15366
                 S.STEAK        0.17795
                MW.HMBRGR       0.10896
                MW.ROAST        0.14678
                MW.STEAK        0.19817
                 W.HMBRGR       0.13559
                 W.ROAST        0.14481
                 W.STEAK        0.23876  /

           B(DR,U3)  VALUE OF PARAMETER ON QUANTITY INDEX
                 /NNE.HMBRGR     .01019
                  NNE.ROAST     -.00039
                  NNE.STEAK     -.00043
                  S.HMBRGR      -.02012
                  S.ROAST       -.00645
                  S.STEAK       -.01463
                  MW.HMBRGR      .01050
                  MW.ROAST       .00537
                  MW.STEAK       .00457
                   W.HMBRGR      .00377
                   W.ROAST      -.01690
                   W.STEAK      -.00360  /

          YM(DR,U4)   QUANTITY CONSUMED OF EXOGENOUS MEAT PRODUCT
               /NNE.PORK            2.515
                NNE.OTHMEAT         2.207
                NNE.CHICKENW        0.977
                NNE.CHICKENP        0.941
                NNE.OTHPOULT        0.495
                  S.PORK            3.321
                  S.OTHMEAT         1.714
                  S.CHICKENW        1.593
                  S.CHICKENP        0.560
                  S.OTHPOULT        0.407
                 MW.PORK            2.963
                 MW.OTHMEAT         2.404
                 MW.CHICKENW        1.235
                 MW.CHICKENP        0.793
                 MW.OTHPOULT        0.212
                  W.PORK            2.806
                  W.OTHMEAT         1.997
                  W.CHICKENW        0.748
                  W.CHICKENP        0.467
                  W.OTHPOULT        0.375  /
```

```
PARAMETER  YOM(DR,U4)   ADJUSTED  LEVEL EXOGENOUS MEAT PRODUCT (LBS);
           YOM(DR,'PORK')=1*YM(DR,'PORK');
           YOM(DR,'OTHMEAT')=1*YM(DR,'OTHMEAT');
           YOM(DR,'CHICKENW')=1*YM(DR,'CHICKENW');
           YOM(DR,'CHICKENP')=1*YM(DR,'CHICKENP');
           YOM(DR,'OTHPOULT')=1*YM(DR,'OTHPOULT');

PARAMETER  EX(DR)     TOTAL EXPENDITURE ON MEAT
                     /NNE    25.606
                      S      26.849
                      MW     27.938
                      W      28.963 /

           QI(DR)     QUANTITY INDEX
                     / NNE    .59412
                       S      .7602
                       MW     .82731
                       W      .76248 /

           P(DR)     POPULATION
                      / NNE    5.5650949E+07
                        S      7.6352485E+07
                        MW     5.9955417E+07
                        W      5.1790655E+07 /

PARAMETER       PA(DR) POPULATION ADJUSTMENT PARAMETER;
                PA(DR)=P(DR)/(2.5);
DISPLAY PA;
PARAMETER       REX(DR) TOTAL REGIONAL EXPENDITURE;
                REX(DR)=EX(DR)*PA(DR);

PARAMETER       RYOM(DR,U4) TOTAL REGIONAL CONSUMPTION OF EXOGENOUS MEATS;
                RYOM(DR,U4)=YOM(DR,U4)*PA(DR);

PARAMETER       ROM(DR,U3)  OTHERMEAT CONSTANT;
                ROM(DR,U3)=SUM(U4, CIJ(U3,U4,DR)*LOG(RYOM(DR,U4)));
DISPLAY ROM;

PARAMETER       DINTC(DR,U3)  INTERCEPT ON DEMAND EQUATIONS;
        DINTC('mw','roast')=ROM('mw','roast')-B('mw','roast')*QI('mw')
                            +.8*A('mw','roast');
        DINTC('mw','steak')=ROM('mw','steak')-B('mw','steak')*QI('mw')
                            +.85*A('mw','steak');
        DINTC('mw','hmbrgr')=ROM('mw','hmbrgr')-B('mw','hmbrgr')*QI('mw')
                            +.9*A('mw','hmbrgr');
        DINTC('w','roast')=ROM('w','roast')-B('w','roast')*QI('w')
                            +.765*A('w','roast');
        DINTC('w','steak')=ROM('w','steak')-B('w','steak')*QI('w')
                            +.88*A('w','steak');
        DINTC('w','hmbrgr')=ROM('w','hmbrgr')-B('w','hmbrgr')*QI('w')
                            +.92*A('w','hmbrgr');
        DINTC('nne','roast')=ROM('nne','roast')-B('nne','roast')*QI('nne')
                            +.94*A('nne','roast');
        DINTC('nne','steak')=ROM('nne','steak')-B('nne','steak')*QI('nne')
                            +1.02*A('nne','steak');
        DINTC('nne','hmbrgr')=ROM('nne','hmbrgr')-B('nne','hmbrgr')*QI('nne')
                            +.95*A('nne','hmbrgr');
        DINTC('s','roast')=ROM('s','roast')-B('s','roast')*QI('s')
                            +.78*A('s','roast');
        DINTC('s','steak')=ROM('s','steak')-B('s','steak')*QI('s')
                            +.87*A('s','steak');
        DINTC('s','hmbrgr')=ROM('s','hmbrgr')-B('s','hmbrgr')*QI('s')
                            +.87*A('s','hmbrgr');

DISPLAY DINTC;

TABLE PEX(EXX,U3) PRICE FOR BOXED CUTS IN FOREIGN MARKETS
            HMBRGR    ROAST     STEAK
     EXX1               260       360
     EXX2
     EXX3
     EXX4
     EXX5

TABLE RIC(DR,U3)  AWAY FROM HOME CONSUMPTION  (CWT)
            HMBRGR          ROAST           STEAK
     NNE    3.685E+06       1.5296E+06      1.7382E+06
     S      4.6887E+06      1.7957E+06      3.4916E+06
     MW     4.4801E+06      1.4934E+06      1.8864E+06
     W      3.3253E+06      1.0278E+06      1.6929E+06
$eject
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*#####################################################################
*######     THE TRANSPORTATION PARAMETERS  (Includes shrinkage due  ######
*######     to transport, distances and cost per hd)                ######
*#####################################################################
TABLE  SHR6(SRR,SR)  SHRINKAGE OF CALVES & NON-FED BEEF BETWEEN REGIONS (HD)
          SE    MW    SW    W     PL
SE       .964  .913 .928 .89   .908
MW       .913  .965 .922 .90   .943
SW       .928  .922 .959 .904  .932
W        .89   .90  .904 .945  .912
PL       .908  .943 .932 .912  .959
TABLE  SHRD(SRD,SR)  SHRINKAGE DAIRY CULLS BETWEEN REGIONS (HD)
          SE    MW    SW    W     PL
SE       .964  .913 .928 .89   .908
MW       .913  .965 .922 .90   .943
SW       .928  .922 .959 .904  .932
W        .89   .90  .904 .945  .912
PL       .908  .943 .932 .912  .959
NNE

TABLE SHR(SRR,SR,U9)  SHRINKAGE OF FED BEEF TO SLAUGHTER (HD)
    SE.(FB9,FB11*FB13)  MW.(FB9,FB11*FB13)   SW.(FB9,FB11*FB13)
SE             .965           .928                  .931
MW             .928           .964                  .932
SW             .931           .932                  .945
 W             .90            .912                  .926
PL             .926           .936                  .934

+   W.(FB9,FB11*FB13)    PL.(FB9,FB11*FB13)
SE          .90                .926
MW          .912               .936
SW          .926               .934
W           .945               .928
PL          .928               .945


TABLE DST(SRR,SR) BEEF:  DISTANCE BETWEEN SUPPLY REGIONS (MILES)
          SE         MW         SW         PL         W
  SE      50         1090       986
  MW      1090       50         830        425
  SW      986        830        100        600        1352
  PL                 425        600        100        1150
  W                             1352       1150       100

TABLE DSTD(SRD,SR) DAIRY:  DISTANCE BETWEEN SUPPLY REGIONS (MILES)
          SE         MW         SW         PL         W
  SE      50         1090       986
  MW      1090       50         830        425
  SW      986        830        100        600        1352
  PL                 425        600        100        1150
  W                             1352       1150       100

TABLE RATEC(U6,SRR,SR)  TRANSPORT COSTS BEEF CALVES &CULLS (DOL PER CWT)
                    SE      MW      SW      W       PL
(CULL,CALF).SE      .24     3.29    2.97            4.08
(CULL,CALF).MW     3.29      .36    2.37            1.31
(CULL,CALF).SW     2.97     2.61     .44    4.26    1.86
(CULL,CALF).W                       4.50     .54    3.84
(CULL,CALF).PL     4.08     1.31    1.86    3.29     .50

PARAMETER TCC(SRR,SR,U6) ADJ. TRANS. COSTS CALVES & CULLS (DOL PER HD);
         TCC(SRR,SR,U6)=1.21*RATEC(U6,SRR,SR)*DC(SRR,U6);
DISPLAY TCC;

TABLE RATES(U7,SRR,SR)  TRANSPORT COSTS NON-FED BEEF (DOL PER CWT)
                     SE      MW      SW      W       PL
(NFB1,NFB1-5).SE     .24     3.29    2.97            4.08
(NFB1,NFB1-5).MW    3.29      .36    2.37            1.31
(NFB1,NFB1-5).SW    2.97     2.61     .44    4.26    1.86
(NFB1,NFB1-5).W                       4.50     .54    3.84
(NFB1,NFB1-5).PL    4.08     1.31    1.86    3.29     .50

PARAMETER TS(SRR,SR,U7) ADJ. TRANS. COSTS NON-FED BEEF (DOL PER HD);
         TS(SRR,SR,U7)=1.21*RATES(U7,SRR,SR)*DS(SRR,U7);
DISPLAY TS;

TABLE RATEF(U9,SRR,SR)  TRANSPORT COSTS OF FED ANIMALS (DOL PER CWT)
                         SE      MW      SW      W       PL
(FB9,FB11*FB13).SE       .24     3.29    2.97            4.08
(FB9,FB11*FB13).MW      3.29      .36    2.37            1.31
(FB9,FB11*FB13).SW      2.97     2.61     .44    4.26    1.86
(FB9,FB11*FB13).W                         4.50     .54    3.84
(FB9,FB11*FB13).PL      4.08     1.31    1.86    3.29     .50

PARAMETER TF(SRR,SR,U9) ADJ. TRANS. COSTS FED BEEF (DOL PER HD);
         TF(SRR,SR,U9)=1.21*RATEF(U9,SRR,SR)*DAA(SRR,U9);
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DISPLAY TF;

TABLE RATED(U5,SRD,SR)  TRANSPORT COSTS OF DAIRY CULLS (DOL PER CWT)
                SE      MW      SW      W       PL
   CULL.SE      .24     3.29    2.97            4.08
   CULL.MW     3.29      .36    2.37            1.31
   CULL.SW     2.97     2.61     .44    4.26    1.86
   CULL.W                       4.50     .54    3.84
   CULL.PL     4.08     1.31    1.86    3.29     .50
PARAMETER TD(SRD,SR,U5) ADJ. TRANS. DAIRY CULLS (DOL PER HD);
          TD(SRD,SR,U5)=1.21*RATED(U5,SRD,SR)*DARYWT(SRD,U5);
DISPLAY TD;

TABLE  SHRDD(SR,DR)  SHRINKAGE FINAL PRODUCTS BETWEEN REGIONS (HD)
          NNE    MW    S     W
SE       .996          .996
MW       .996  .996  .996
SW       .996  .996  .996  .996
W              .996  .996  .996
PL       .996  .996  .996  .996

TABLE DD(DR,SR) DISTANCE BETWEEN SUPPLY AND DEMAND REGIONS (MILES)
          SE          MW          SW          PL          W
  NNE     1007        1300        1795        1646
  S       307          975         553        1342        2224
  MW                   446        1134         871
  W                   1289        1210         865         364

PARAMETER T3(DR,SR,U3) TRANSPORT COST BOXED BF TO DMAND REGIONS (CWT);
  T3(DR,SR,U3) $DD(DR,SR)=0.7589+.00258*DD(DR,SR)-(3.35E-07)*SQR(DD(DR,SR));
DISPLAY T3;

TABLE TFI(DR,IM,U3) TRANSPORT COST: IMPORTS (DOLLARS PER CWT)
          IMPORTS.HMBRGR
     NNE
     S          90.2
     MW
     W          90.2
TABLE MRGI(DR,IM,U3) MARKETING MARGIN IMPORTS (DOLLARS PER CWT)
                    HMBRGR      ROAST       STEAK
     NNE.IMPORTS
     S.IMPORTS      60
     MW.IMPORTS
     W.IMPORTS      60

TABLE T2(SR,EXX,U3) TRANSPORT COST BOXED CUTS TO FOREIGN MARKETS (CWT)
          (EXX1*EXX5).HMBRGR     (EXX1*EXX5).(ROAST, STEAK)
     SE
     MW
     SW
     W
     PL
*###############      END OF TRANSPORT SECTION      ############################
*#########################################################################
*###############      WEIGHT ADJUSTMENT SECTION     ############################
$offmargin ontext
    The section below calculates the adjustment to production costs in order to
account for differrences in the starting weights of live animals in a production
activity in a region due to differences in weights between regions of origin.
For example, at the cow-calf stage weaned calves in the midwest region weigh 465
lbs.
while weaned calves in the southeast only weigh 435 lb.  The budget for producing
a 900 lb fed animal in the midwest is based on a starting weight for weaned calves
of 465 lbs.  If a weaned calf from the southeast is shipped to the midwest for
finishing then the cost of producing a 900 lb slaughter animal has to be adjusted
upwards to account for the increased lenght of time the southeast calf needs to
be
fed to reach market weight.  The adjustment in production costs are calculated by
determining the cost of gain in the midwest for bring a weaned calf up to 900 lbs.

Then the difference between the weights of weaned calves in the southeast and the
midwest is multiplied by this rate of gain to determine the cost of bring the calf
from the southeast up to the starting weight of midwest calves.  The adjustment
cost
is divided by the weight of the 900 fed animal to put it into a per head
adjustment.
The adjustment cost is then added onto the cost of transporting weaned calves
from thesoutheast to the midwest.
$offtext

PARAMETER  CLFWT(SR) WEIGHT OF WEANED CALF IN SUPPLY REGIONS;
           CLFWT(SR)=DC(SR,'CALF');
PARAMETER WTDC(SR,SRR,U6) DIFF.IN WGHTS OF CALVES & CULLS BETWEEN REG. (CWT);

        WTDC('SE','SE',U6)=DC('SE',U6)-DC('SE',U6);
        WTDC('SE','MW',U6)=DC('MW',U6)-DC('SE',U6);
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          WTDC('SE','SW',U6)=DC('SW',U6)-DC('SE',U6);
          WTDC('SE','W',U6)=DC('W',U6)-DC('SE',U6);
          WTDC('SE','PL',U6)=DC('PL',U6)-DC('SE',U6);

          WTDC('MW','SE',U6)=DC('SE',U6)-DC('MW',U6);
          WTDC('MW','MW',U6)=DC('MW',U6)-DC('MW',U6);
          WTDC('MW','SW',U6)=DC('SW',U6)-DC('MW',U6);
          WTDC('MW','W',U6)=DC('W',U6)-DC('MW',U6);
          WTDC('MW','PL',U6)=DC('PL',U6)-DC('MW',U6);
          WTDC('SW','SE',U6)=DC('SE',U6)-DC('SW',U6);
          WTDC('SW','MW',U6)=DC('MW',U6)-DC('SW',U6);
          WTDC('SW','SW',U6)=DC('SW',U6)-DC('SW',U6);
          WTDC('SW','W',U6)=DC('W',U6)-DC('SW',U6);
          WTDC('SW','PL',U6)=DC('PL',U6)-DC('SW',U6);
          WTDC('W','SE',U6)=DC('SE',U6)-DC('W',U6);
          WTDC('W','MW',U6)=DC('MW',U6)-DC('W',U6);
          WTDC('W','SW',U6)=DC('SW',U6)-DC('W',U6);
          WTDC('W','W',U6)=DC('W',U6)-DC('W',U6);
          WTDC('W','PL',U6)=DC('PL',U6)-DC('W',U6);

          WTDC('PL','SE',U6)=DC('SE',U6)-DC('PL',U6);
          WTDC('PL','MW',U6)=DC('MW',U6)-DC('PL',U6);
          WTDC('PL','SW',U6)=DC('SW',U6)-DC('PL',U6);
          WTDC('PL','W',U6)=DC('W',U6)-DC('PL',U6);
          WTDC('PL','PL',U6)=DC('PL',U6)-DC('PL',U6);

display wtdc;
*#######       COW-CALF TO STOCKER STAGE      ################
PARAMETER  WT67(SR) WEIGHT GAINED FROM CALF TO NFB1 (CWT);
         WT67(SR)=DS(SR,'NFB1')-DC(SR,'CALF');
DISPLAY WT67;
PARAMETER  G7(SR)  COST OF GAIN AT STOCKER STAGE (DOL PER CWT);
         G7(SR)=R7(SR,'NFB1')/WT67(SR);
DISPLAY G7;
PARAMETER ADJ(SR,SRR)  COST OF AJUSTMENT (DOL PER HD);
     ADJ(SR,SRR)=WTDC(SR,SRR,'CALF')*G7(SRR);
display adj;

*#######       COW-CALF TO FINISH STAGE ################
PARAMETER  WT68(SR) WEIGHT GAINED FROM CALF TO FINISHING (CWT);
         WT68(SR)=DAA(SR,'FB9')-CLFWT(SR);
DISPLAY WT68;
PARAMETER  G68(SR)  COST OF CALF GAIN AT FINISHING STAGE (DOL PER CWT);
         G68(SR)=R8(SR,'FB9')/WT68(SR)   ;
DISPLAY G68;
PARAMETER ADJCF(SR,SRR)  COST OF AJUSTMENT CALF TO FEEDLOT (DOL PER HD);
    ADJCF(SR,SRR)=WTDC(SR,SRR,'CALF')*G68(SRR);
DISPLAY ADJCF;

*#######       STOCKER TO FINISH STAGE  ################
PARAMETER  NFBWT(SR,U7)  WEIGHT OF NFB IN SUPPLY REGIONS;
           NFBWT(SR,U7)=DS(SR,U7);
PARAMETER WTDS(SR,SRR,U7) DIFFERENCES IN WGHTS OF NFB BETWEEN REGIONS (CWT);
         WTDS('SE','SE',U7)=DS('SE',U7)-DS('SE',U7);
         WTDS('SE','MW',U7)=DS('MW',U7)-DS('SE',U7);
         WTDS('SE','SW',U7)=DS('SW',U7)-DS('SE',U7);
         WTDS('SE','W',U7)=DS('W',U7)-DS('SE',U7);
         WTDS('SE','PL',U7)=DS('PL',U7)-DS('SE',U7);

         WTDS('MW','SE',U7)=DS('SE',U7)-DS('MW',U7);
         WTDS('MW','MW',U7)=DS('MW',U7)-DS('MW',U7);
         WTDS('MW','SW',U7)=DS('SW',U7)-DS('MW',U7);
         WTDS('MW','W',U7)=DS('W',U7)-DS('MW',U7);
         WTDS('MW','PL',U7)=DS('PL',U7)-DS('MW',U7);

         WTDS('SW','SE',U7)=DS('SE',U7)-DS('SW',U7);
         WTDS('SW','MW',U7)=DS('MW',U7)-DS('SW',U7);
         WTDS('SW','SW',U7)=DS('SW',U7)-DS('SW',U7);
         WTDS('SW','W',U7)=DS('W',U7)-DS('SW',U7);
         WTDS('SW','PL',U7)=DS('PL',U7)-DS('SW',U7);

         WTDS('W','SE',U7)=DS('SE',U7)-DS('W',U7);
         WTDS('W','MW',U7)=DS('MW',U7)-DS('W',U7);
         WTDS('W','SW',U7)=DS('SW',U7)-DS('W',U7);
         WTDS('W','W',U7)=DS('W',U7)-DS('W',U7);
         WTDS('W','PL',U7)=DS('PL',U7)-DS('W',U7);

         WTDS('PL','SE',U7)=DS('SE',U7)-DS('PL',U7);
         WTDS('PL','MW',U7)=DS('MW',U7)-DS('PL',U7);
         WTDS('PL','SW',U7)=DS('SW',U7)-DS('PL',U7);
         WTDS('PL','W',U7)=DS('W',U7)-DS('PL',U7);
         WTDS('PL','PL',U7)=DS('PL',U7)-DS('PL',U7);
DISPLAY WTDS;

PARAMETER  WT78(SR,U7) WEIGHT GAINED FROM STOCKER TO FINISHING (CWT);
         WT78(SR,'NFB1')=DAA(SR,'FB9')-DS(SR,'NFB1');
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          WT78(SR,'NFB1-5')=DAA(SR,'FB11')-DS(SR,'NFB1-5');
  DISPLAY WT78;
  PARAMETER  G78(SR,U7)  COST OF GAIN AT FINISHING STAGE (DOL PER CWT);
          G78(SR,'NFB1')=R8(SR,'NFB1-FB9')/WT78(SR,'NFB1');
          G78(SR,'NFB1-5')=R8(SR,'NFB2-FB11')/WT78(SR,'NFB1-5');
  DISPLAY G78;
  PARAMETER ADJ8F(SR,SRR,U7)  COST OF AJUSTMENT (DOL PER HD);
      ADJSF(SR,SRR,U7)=WTDS(SR,SRR,U7)*G78(SRR,U7);
  DISPLAY ADJ8F;

  *######################  NFB & FB TO SLAUGHTER  ##############################
  PARAMETER WTDFB(SR,SRR,U9) DIFF. IN WGHTS OF FED SLGHTR ANIMALS BETWEEN REG.;
          WTDFB('SE','SE',U9)=DAA('SE',U9)-DAA('SE',U9);
          WTDFB('SE','MW',U9)=DAA('MW',U9)-DAA('SE',U9);
          WTDFB('SE','SW',U9)=DAA('SW',U9)-DAA('SE',U9);
          WTDFB('SE','W',U9)=DAA('W',U9)-DAA('SE',U9);
          WTDFB('SE','PL',U9)=DAA('PL',U9)-DAA('SE',U9);

          WTDFB('MW','SE',U9)=DAA('SE',U9)-DAA('MW',U9);
          WTDFB('MW','MW',U9)=DAA('MW',U9)-DAA('MW',U9);
          WTDFB('MW','SW',U9)=DAA('SW',U9)-DAA('MW',U9);
          WTDFB('MW','W',U9)=DAA('W',U9)-DAA('MW',U9);
          WTDFB('MW','PL',U9)=DAA('PL',U9)-DAA('MW',U9);

          WTDFB('SW','SE',U9)=DAA('SE',U9)-DAA('SW',U9);
          WTDFB('SW','MW',U9)=DAA('MW',U9)-DAA('SW',U9);
          WTDFB('SW','SW',U9)=DAA('SW',U9)-DAA('SW',U9);
          WTDFB('SW','W',U9)=DAA('W',U9)-DAA('SW',U9);
          WTDFB('SW','PL',U9)=DAA('PL',U9)-DAA('SW',U9);
          WTDFB('W','SE',U9)=DAA('SE',U9)-DAA('W',U9);
          WTDFB('W','MW',U9)=DAA('MW',U9)-DAA('W',U9);
          WTDFB('W','SW',U9)=DAA('SW',U9)-DAA('W',U9);
          WTDFB('W','W',U9)=DAA('W',U9)-DAA('W',U9);
          WTDFB('W','PL',U9)=DAA('PL',U9)-DAA('W',U9);

          WTDFB('PL','SE',U9)=DAA('SE',U9)-DAA('PL',U9);
          WTDFB('PL','MW',U9)=DAA('MW',U9)-DAA('PL',U9);
          WTDFB('PL','SW',U9)=DAA('SW',U9)-DAA('PL',U9);
          WTDFB('PL','W',U9)=DAA('W',U9)-DAA('PL',U9);
          WTDFB('PL','PL',U9)=DAA('PL',U9)-DAA('PL',U9);
  DISPLAY WTDFB;
  PARAMETER ADJSLF(SR,SRR,L,U9)  COST OF AJUSTMENT (DOL PER HD);
      ADJSLF(SR,SRR,L,U9)=(WTDFB(SR,SRR,U9)/DAA(SRR,U9))*R1(SRR,L);
  DISPLAY ADJSLF;
  PARAMETER ADJSLS(SR,SRR,L,U7) COST ADJUSTMENT NFB TO SLAUGHTER (DOL PER HD);
       ADJSLS(SR,SRR,L,U7)=WTDS(SR,SRR,U7)/DS(SRR,U7)*R1(SRR,L);
  DISPLAY ADJSLS;
  PARAMETER ADJSLC(SR,SRR,L,U6) COST OF ADJUSTMENT CULL TO SLAUGHTER (D PER HD);
       ADJSLC(SR,SRR,L,'CULL')=WTDC(SR,SRR,'CULL')/DC(SRR,'CULL')*R1(SRR,L);
  DISPLAY ADJSLC;

  *#############  DAIRY CULL ADJUSTMENT    ##############################
  PARAMETER WTDD(SRD,SR,U5) DIFF. IN WGHTS OF DAIRY CULLS BETWEEN REG.;
          WTDD('SE','SE',U5)=DARYWT('SE',U5)-DARYWT('SE',U5);
          WTDD('SE','MW',U5)=DARYWT('MW',U5)-DARYWT('SE',U5);
          WTDD('SE','SW',U5)=DARYWT('SW',U5)-DARYWT('SE',U5);
          WTDD('SE','W',U5)=DARYWT('W',U5)-DARYWT('SE',U5);
          WTDD('SE','PL',U5)=DARYWT('PL',U5)-DARYWT('SE',U5);

          WTDD('MW','SE',U5)=DARYWT('SE',U5)-DARYWT('MW',U5);
          WTDD('MW','MW',U5)=DARYWT('MW',U5)-DARYWT('MW',U5);
          WTDD('MW','SW',U5)=DARYWT('SW',U5)-DARYWT('MW',U5);
          WTDD('MW','W',U5)=DARYWT('W',U5)-DARYWT('MW',U5);
          WTDD('MW','PL',U5)=DARYWT('PL',U5)-DARYWT('MW',U5);

          WTDD('SW','SE',U5)=DARYWT('SE',U5)-DARYWT('SW',U5);
          WTDD('SW','MW',U5)=DARYWT('MW',U5)-DARYWT('SW',U5);
          WTDD('SW','SW',U5)=DARYWT('SW',U5)-DARYWT('SW',U5);
          WTDD('SW','W',U5)=DARYWT('W',U5)-DARYWT('SW',U5);
          WTDD('SW','PL',U5)=DARYWT('PL',U5)-DARYWT('SW',U5);

          WTDD('W','SE',U5)=DARYWT('SE',U5)-DARYWT('W',U5);
          WTDD('W','MW',U5)=DARYWT('MW',U5)-DARYWT('W',U5);
          WTDD('W','SW',U5)=DARYWT('SW',U5)-DARYWT('W',U5);
          WTDD('W','W',U5)=DARYWT('W',U5)-DARYWT('W',U5);
          WTDD('W','PL',U5)=DARYWT('PL',U5)-DARYWT('W',U5);

          WTDD('PL','SE',U5)=DARYWT('SE',U5)-DARYWT('PL',U5);
          WTDD('PL','MW',U5)=DARYWT('MW',U5)-DARYWT('PL',U5);
          WTDD('PL','SW',U5)=DARYWT('SW',U5)-DARYWT('PL',U5);
          WTDD('PL','W',U5)=DARYWT('W',U5)-DARYWT('PL',U5);
          WTDD('PL','PL',U5)=DARYWT('PL',U5)-DARYWT('PL',U5);
  DISPLAY WTDD;
  PARAMETER ADJSLD(SRD,SR,L,U5) COST OF ADJ. DAIRY CULL TO SLAUGHTER (D PER HD);
      ADJSLD(SRD,SR,L,'CULL')=WTDD(SRD,SR,'CULL')/DARYWT(SRD,'CULL')*R1(SR,L)
                              $DSTD(SRD,SR);
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DISPLAY ADJSLD;

*#####################################################################
*#####   parameters used to calculate starting values
*#####################################################################

Table  bfcnsmptn(dr,u3)   MONTHLY HOUSEHOLD CONSUMPTION (lbs.)
      HMBRGR     ROAST     STEAK
NNE   4.204      1.738     1.988
S     3.890      1.513     2.89
MW    4.65       1.53      1.999
W     4.022      1.266     2.069

PARAMETER  BEEF(DR,U3)  regional consumption of beef (cwt.);
           BEEF(DR,U3)=PA(dr)*bfcnsmptn(dr,u3);
DISPLAY BEEF;
TABLE PRICE(DR,U3)  Retail Price of Beef (DOLLARS PER LB.)
          hmbrgr      roast     steak
nne        1.614      2.344     3.541
s          1.724      2.414     2.343
mw         1.605      2.264     2.689
w          1.733      2.546     3.196
DISPLAY PRICE;
*############       END OF DATA SECTION      ################################
$offmargin ontext
*#####################################################################
*############     Display of Combined Parameters        ###################

parameter ppn(sr) NO. OF PLANTS IN EACH REGION
     /    SE   1
          MW   5
          SW   5
          W    1
          PL   3  /
parameter check(sr,dr,u3,k1)   cost of supplying regions;
 check(sr,dr,'roast',k1) $dd(dr,sr) = t3(dr,sr,'roast')
                       +(sum(l,r1(sr,l))/ppn(sr))
                       *CUTOUT('roast',K1)/D2(SR,'roast',K1);
 check(sr,dr,'steak',k1) $dd(dr,sr) = t3(dr,sr,'steak')
                       +(sum(l,r1(sr,l))/ppn(sr))
                       *CUTOUT('steak',K1)/D2(SR,'steak',K1);
display check;
parameter costfs1(sr,srr,l,u9)  cost of slghtrng fed beef by region of origin;
     costfs1(sr,srr,l,u9) $dsr1(sr,srr,l)=
     tf(sr,srr,u9)+adjslf(sr,srr,l,u9)+r1(srr,l);
display costfs1;
parameter costff1(sr,srr,u8,k8)  cost of finishing fed beef by region of origin;
     costff1(sr,srr,'calf','fb9') $dst(sr,srr)=
     tcc(sr,srr,'calf')+adjcf(sr,srr)+r8(srr,'fb9');
display costff1;
parameter catstck(sr,srr,u6,k7)  cost of finishing fed beef by region of origin;
     catstck(sr,srr,'calf','nfb1') $dst(sr,srr)=
     tcc(sr,srr,'calf')+adj(sr,srr)+r7(srr,'nfb1');
display catstck;
$offtext
parameter tc1(sr)  total cost of producing non-fed beef 1200 (per head);
          tc1(sr)=r6(sr,'calf')+r7(sr,'nfb1')+r8(sr,'fb12')+r1(sr,'pl1');
parameter tc2(sr)  total cost of producing non-fed beef 900 (per head);
          tc2(sr)=r6(sr,'calf')+r7(sr,'nfb1')+r8(sr,'nfb1-fb9')+r1(sr,'pl1');
parameter tc5(sr)  total cost of producing non-fed beef 1100 (per head);
          tc5(sr)=r6(sr,'calf')+r7(sr,'nfb1-5')+r8(sr,'nfb2-fb11')+r1(sr,'pl1');
parameter tc3(sr)  total cost of producing fed beef 1100 (per head);
          tc3(sr)=r6(sr,'calf')+r8(sr,'fb11')+r1(sr,'pl1');
parameter tc4(sr)  total cost of producing fed beef 900 (per head);
          tc4(sr)=r6(sr,'calf')+r8(sr,'fb9')+r1(sr,'pl1');

parameter tcw1(sr)  total cost of producing non-fed beef 1200 (per cwt);
          tcw1(sr)=tc1(sr)/d1(sr,'fb12');
parameter tcw2(sr)  total cost of producing non-fed beef 900 (per cwt);
          tcw2(sr)=tc2(sr)/d1(sr,'fb9');
parameter tcw5(sr)  total cost of producing non-fed beef 1100 (per cwt);
          tcw5(sr)=tc5(sr)/d1(sr,'fb11');
parameter tcw3(sr)  total cost of producing fed beef 1100 (per cwt);
          tcw3(sr)=tc3(sr)/d1(sr,'fb11');
parameter tcw4(sr)  total cost of producing fed beef 900 (per cwt);
          tcw4(sr)=tc4(sr)/d1(sr,'fb9');

display tc1;
display tc2;
display tc3;
display tc4;
display tcw1;
display tcw2;
display tcw3;
display tcw4;
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POSITIVE VARIABLES

*       TRANSPORTATION
         XX(SRR,SR,U6)      CALVES SHIPPED TO STOCKER (HD)
         XXC(SRR,SR,U6)     CALVES SHIPPED TO FEEDLOT (HD)
         XXS(SRR,SR,U7)     STOCKERS SHIPPED TO FEEDLOT (HD)
         XXXC(SRR,SR,L,U6)  BEEF CULLS SHIPPED TO SLAUGHTER( HD)
         XXXS(SRR,SR,L,U7)  NON-FED SHIPPED TO SLAUGHTER (HD)
         XXXF(SRR,SR,L,U9)  FINISHED ANIMALS SHIPPED (HD)
         XXXD(SRD,SR,L,U6)  DAIRY CULLS SHIPPED (HD)
         XF(IM,DR,U3)       QUANTITY OF FOREIGN HAMBURGER SHIPPED (CWT)
         X2(SR,EXX,U3)      QUANTITY OF BOXED BEEF SHIPPED OVERSEAS (CWT)
         X(SR,DR,U3)        QUANTITY OF FINAL PRODUCT SHIPPED (CWT)

*       PRODUCTION PROCESSES
         Q6(SR,K6)           QUANTITY OF LIVE ANIMALS SUPPLIED
         Q7(SR,K7)           HEAD STOCKERED
         Q8(SR,K8)           HEAD FINISHED
         Q1(SR,L,K1)         HEAD SLAUGHTERED
         Q1A(SR,L)           HEAD OF CATTLE SLAUGHTERED IN PLANT L
         Q2(SR,K2)           LEVEL OF FABRICATION PROCESS UTILIZED (HD)
         Q3(SR,L,U2)         LEVEL OF HAMBURGER PROCESS USED (CWT)

*       PRODUCTS USED AND PRODUCED
         ZD(SRD,U5)          DAIRY CULLS SUPPLIED TO SLAUGHTER (HD)
*         Z5(SR,K6)          BREEDING STOCK AVAILABLE  (HD)
         Z6(SR,U6)           WEANED CALVES AND CULLS PRODUCED (HD)
         Z77(SR,U6)          WEANED ANIMALS STOCKERED (HD)
         Z7(SR,U7)           STOCKERED ANIMALS PRODUCED BY PRODUCTION ACTIVITY (HD)
         Z8FL(SR,U8)         CATTLE USED IN THE FEEDLOT (HD)
         Z8(SR,U9)           FED ANIMALS PRODUCED BY PRODUCTION ACTIVITY (HD)
         Z0(SR,L,U0)         ANIMALS SUPPLIED USED IN SLAUGHTER (HD)
         Z1(SR,L,U2,K1)      QUANTITY OF FAB CUTS PRODUCED (CWT).
         Z1H(SR,L,U2)        PRIMAL CUTS USED FOR HAMBURGER  (CWT)
         Z1R(SR,L,U2)        PRIMAL CUTS ALLOCATED TO RETAIL (CWT)
         Z(SR,U3)            QUANT PROCESSED MEAT PRODUCED
         Y(DR,U3)            MONTHLY HOUSEHOLD CONSUMPTION OF BEEF (LBS)
         AHY(DR,U3)          ANNUAL AWAY FROM HOME CONSUMPTION (CWT)
         BFEXPRT(EXX,U3)     FOREIGN CONSUMPTION OF BEEF (CWT)

       FREE VARIABLES
         NSB        NET SOCIAL BENEFIT (VALUE OF LINE INTERGRAL)
         NSR        NET SOCIAL REVENUE (VALUE OF LP OBJECTIVE FUNCTION);

 EQUATIONS
*########  LIVE ANIMAL DEFEINITIONS      ####################################
   DAIRYCULLS(SRD)          DAIRY CULLS SUPPLY CONSTRAINT
   DAIRYTRANS(SRD)          DAIRY CULL SHIPMENTS TO SLAUGHTER
   BRDNGSTCK(SR,K6)         AVAIALBILTY OF BREEDING STOCK
   LIVESPPLY(SR,U6)         PRODUCTION OF CULLS &CALVES
   TRANCULL6(SR)            CULL SHIPMENTS TO OTHER STAGE
   TRANCALF6(SR)            WEANED CALF SHIPMENTS TO OTHER STAGE
   CCTOSTK(SRR)             WEANED CALVES SHIPPED IN TO STOCKER STAGE
   CCUSEDSTK(SR)            WEANED CALVES UTILIED IN STOCKER STAGE
   PLACESTCK(SR,U7)         PRODUCTION OF STOCKERS
   TRANSFER71(SR)           YEARLING SHIPMENTS TO FEEDLOT & SLAUGHTER
   TRANSFER72(SR)           LONG YEARLING SHIPMENTS TO FEEDLOT & SLAUGHTER
   CCSTCK1(SRR)             CALVES SHIPMENTS INTO FINISHING STAGE
   CCSTCK2(SRR)             YEARLING SHIPMENTS INTO FINISHING STAGE
   CCSTCK3(SRR)             LONG YEARLING SHIPMENTS INTO FINISHING STAGE
   LVANUSEFL(SR,U8)         LIVE ANIMALS UTILIZATION IN FINISHING STAGE
   FINISHFL(SR,U9)          FED BEEF PRODUCTION

   TRANSFER8(SR,U9)         SHIPMENTS OF FED BEFF TO SLAUGHTER
   TOSLGHT1(SRR,L)       FED SHIPMENTS INTO THE SLAUGHTER STAGE (900)
   TOSLGHT2(SRR,L)       FED SHIPMENTS INTO THE SLAUGHTER STAGE (1100)
   TOSLGHT3(SRR,L)       FED SHIPMENTS INTO THE SLAUGHTER STAGE (1200)
   TOSLGHT4(SRR,L)       FED SHIPMENTS INTO THE SLAUGHTER STAGE (1300)
   TOSLGHT5(SRR,L)       NON-FED SHIPMENTS INTO THE SLAUGHTER STAGE (YEARLING)
   TOSLGHT6(SRR,L)       NON-FED SHIPMENTS INTO THE SLAUGHTER STAGE (1.5 YEARS)
   TOSLGHT7(SRR,L)       CULL SHIPMENTS INTO THE SLAUGHTER STAGE


*########       SLAUGHTER DEFINITIONS          ############################

   INTERMED1(SR,L,U0)     SLAUGHTER:  LIVE ANIMAL USAGE
   FABRICAT(SR,L,U2,K1)   SLAUGHTER:  PRIMAL CUTS PRODUCED
   PLNTAGG(SR,L)          CAPACITY:  HEAD CATTLE SLAUGHTERED IN PLANT L
   PLCPCTY(SR,L)          CAPACITY:  CAPACITY PLANT L
   ALLOCFAB(SR,L,U2)      TRANSFER:  ALLOCATION OF CUTS TO HB AND RETAIL
   RSTRTL(SR)             TRANSFER:  AGGREGATION OF ROAST TO REGION SALE
   STKRTL(SR)             TRANSFER:  AGGREGATION OF STEAK TO REGION SALE
   INTERMED3(SR,L,U2)     PROCESSING:  USE OF PRIMAL CUTS TO MAKE HB
   HAMBURGER(SR)          PROCESSING:  MAKING HAMBURGER
   FATMINM(SR,L)          PROCESSING:  MINIMUM FAT CONTENT HAMBURGER
   FATMAXM(SR,L)          PROCESSING:  MAXIMUM FAT CONTENT HAMBURGER
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    SALE(SR,U3)              TRANSFER: SALE OF TABLE CUTS & HAMBURGER
    EXTRNSPRT(EXX,U3)        TRANSPORTATION: FOREIGN BEEF EXPORT BALANCE
    IMTRNSPRT(IM,U3)         TRANSPORTATION: FOREIGN BEEF IMPORT BALANCE
    CNSMPTN(DR,U3)           PURCHASE OF RETAIL CUTS BY CONSUMERS
    AHCNSMPTN(DR,U3)         AWAY FROM HOME CONSUMPTION RESTRICTION
    WLFR1                    NET SOCIAL WELFARE;

*DAIRY
DAIRYCULLS(SRD)..      -DAIRY(SRD,'CULL')+ZD(SRD,'CULL')=L=0;

DAIRYTRANS(SRD)..      -ZD(SRD,'CULL')
                       +SUM((SR,L)$DSRLD(SRD,SR,L), XXXD(SRD,SR,L,'CULL'))
                       =L=0;
*COW-CALF
 BRDNGSTCK(SR,K6)..   -Z5(SR,K6) + C6(SR,K6)*Q6(SR,K6)
                      =L=0;

 LIVESPPLY(SR,U6)..   Z6(SR,U6)-SUM(K6, D6(SR,U6,K6)*Q6(SR,K6))
                      =E=0;

 TRANCULL6(SR)..     -Z6(SR,'CULL')
                      +SUM((SRR,L)$DSRL(SR,SRR,L), XXXC(SR,SRR,L,'CULL'))
                      =L=0;
 TRANCALF6(SR)..     -Z6(SR,'CALF')
                      +SUM(SRR $DST(SR,SRR), XX(SR,SRR,'CALF'))
                      +SUM(SRR $DST(SR,SRR), XXC(SR,SRR,'CALF'))
                      =L=0;

*STOCKER
CCTOSTK(SRR)..       -SUM(SR $DST(SR,SRR), SHR6(SR,SRR)*XX(SR,SRR,'CALF'))
                     +Z77(SRR,'CALF')
                     =L=0;


CCUSEDSTK(SR)..
                     -Z77(SR,'CALF')+SUM(K7, C7(SR,'CALF',K7)*Q7(SR,K7))
                      =E=0;


PLACESTCK(SR,U7)..
                      Z7(SR,U7)-SUM(K7, D7(SR,U7,K7)*Q7(SR,K7))
                      =E=0;
TRANSFER71(SR)..     -Z7(SR,'NFB1')
                     +SUM(SRR $DST(SR,SRR), XXS(SR,SRR,'NFB1'))
                     +SUM((SRR,L) $DSRL(SR,SRR,L), XXXS(SR,SRR,L,'NFB1'))
                      =L=0;
TRANSFER72(SR)..     -Z7(SR,'NFB1-5')
                     +SUM(SRR $DST(SR,SRR), XXS(SR,SRR,'NFB1-5'))
                     +SUM((SRR,L) $DSRL(SR,SRR,L), XXXS(SR,SRR,L,'NFB1-5'))
                      =L=0;
*FEEDLOT
CCSTCK1(SRR)..    -SUM(SR $DST(SR,SRR), SHR6(SR,SRR)*XXC(SR,SRR,'CALF'))
                  +Z8FL(SRR,'CALF')
                  =L=0;
CCSTCK2(SRR)..    -SUM(SR $DST(SR,SRR), SHR6(SR,SRR)* XXS(SR,SRR,'NFB1'))
                  +Z8FL(SRR,'NFB1')
                  =L=0;
CCSTCK3(SRR)..    -SUM(SR $DST(SR,SRR), SHR6(SR,SRR)* XXS(SR,SRR,'NFB1-5'))
                  +Z8FL(SRR,'NFB1-5')
                  =L=0;

LVANUSEFL(SR,U8)..    -Z8FL(SR,U8)+SUM(K8, C8(SR,U8,K8)*Q8(SR,K8))
                      =E=0;

FINISHFL(SR,U9)..     -SUM(K8, D8(SR,U9,K8)*Q8(SR,K8))
                      +Z8(SR,U9)
                      =E=0;

TRANSFER8(SR,U9)..    -Z8(SR,U9)
                      +SUM((SRR,L) $DSRL(SR,SRR,L), XXXF(SR,SRR,L,U9))
                      =L=0;

*SLAUGHTER-PROCESSING
TOSLGHT1(SRR,L) $SRL(SRR,L)..
          -SUM(SR $DSRL(SR,SRR,L), SHR(SR,SRR,'FB9')*XXXF(SR,SRR,L,'FB9'))
          +Z0(SRR,L,'FB9')
          =L=0;
TOSLGHT2(SRR,L) $SRL(SRR,L)..
          -SUM(SR $DSRL(SR,SRR,L), SHR(SR,SRR,'FB11')*XXXF(SR,SRR,L,'FB11'))
          +Z0(SRR,L,'FB11')
          =L=0;
TOSLGHT3(SRR,L) $SRL(SRR,L)..
          -SUM(SR $DSRL(SR,SRR,L), SHR(SR,SRR,'FB12')*XXXF(SR,SRR,L,'FB12'))
          +Z0(SRR,L,'FB12')
          =L=0;
TOSLGHT4(SRR,L) $SRL(SRR,L)..
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          -SUM(SR $DSRL(SR,SRR,L), SHR(SR,SRR,'FB13')*XXXF(SR,SRR,L,'FB13'))
          +Z0(SRR,L,'FB13')
          =L=0;
TOSLGHT5(SRR,L) $SRL(SRR,L)..
          -SUM(SR $DSRL(SR,SRR,L), SHR6(SR,SRR)*XXXS(SR,SRR,L,'NFB1'))
          +Z0(SRR,L,'NFB1')
          =L=0;
TOSLGHT6(SRR,L) $SRL(SRR,L)..
          -SUM(SR $DSRL(SR,SRR,L), SHR6(SR,SRR)*XXXS(SR,SRR,L,'NFB1-5'))
          +Z0(SRR,L,'NFB1-5')
          =L=0;
TOSLGHT7(SRR,L) $SRL(SRR,L)..
          -SUM(SR $DSRL(SR,SRR,L), SHR6(SR,SRR)*XXXC(SR,SRR,L,'CULL'))
          -SUM(SRD $DSRLD(SRD,SRR,L), SHRD(SRD,SRR)*XXXD(SRD,SRR,L,'CULL'))
          +Z0(SRR,L,'CULL')
          =L=0;

INTERMED1(SR,L,U0) $SRL(SR,L)..  -Z0(SR,L,U0)
                    +SUM(K1 $SRLPC(SR,L,U0,K1), C1(SR,L,U0,K1)*Q1(SR,L,K1))
                    =E=0;
FABRICAT(SR,L,U2,K1) $SRL(sr,1)..  Z1(SR,L,U2,K1)
                    -D2(SR,U2,K1)*Q1(SR,L,K1)
                    =E=0;


PLNTAGG(SR,L) $SRL(SR,L).. +SUM(K1, Q1(SR,L,K1)) -Q1A(SR,L)=E=0;

PLCPCTY(SR,L) $SRL(SR,L)..  Q1A(SR,L)-TCAPCTY(SR,L)=L=0;

ALLOCFAB(SR,L,U2) $SRLHB(SR,L,U2).. -SUM(K1 $SRLHB(SR,L,U2), Z1(SR,L,U2,K1))
                  + Z1R(SR,L,U2) $RTL(SR,L,U2)+ Z1H(SR,L,U2) $SRLHB(SR,L,U2)
                  =L=0;

RSTRTL(SR)..   -SUM(L $SRL(SR,L), Z1R(SR,L,'ROAST'))+Z(SR,'ROAST')=E=0;


STKRTL(SR)..   -SUM(L $SRL(SR,L), Z1R(SR,L,'STEAK'))+Z(SR,'STEAK')=E=0;

INTERMED3(SR,L,U2) $SRLHB(SR,L,U2)..  -Z1H(SR,L,U2)
                           +C3(SR,U2)*Q3(SR,L,U2)
                           =E=0;

HAMBURGER(SR)..    Z(SR,'HMBRGR')-SUM((L,U2) $SRLHB(SR,L,U2), Q3(SR,L,U2))
                   =E=0;
FATMINM(SR,L)..  SUM(U2 $SRLHB(SR,L,U2), A3(SR,'MIN',U2)*Q3(SR,L,U2))
                   -FAT(SR,'MIN')*Z(SR,'HMBRGR')=L=0;
FATMAXM(SR,L)..  SUM(U2 $SRLHB(SR,L,U2), A3(SR,'MAX',U2)*Q3(SR,L,U2))
                   -FAT(SR,'MAX')*Z(SR,'HMBRGR')=L=0;

SALE(SR,U3)..  -Z(SR,U3) +SUM(DR $DD(DR,SR), X(SR,DR,U3))
               + SUM(EXX $T2(SR,EXX,U3), X2(SR,EXX,U3))=L=0;

EXTRNSPRT(EXX,U3) $PEX(EXX,U3).. -SUM(SR $PEX(EXX,U3), X2(SR,EXX,U3))
                    +BFEXPRT(EXX,U3)
                    =L=0;
IMTRNSPRT(IM,U3)..    SUM(DR $IMPRTDMND(IM,DR,U3), XF(IM,DR,U3))
                    -BFIMPRT(IM,U3)
                    =L=0;

CNSMPTN(DR,U3)..    -SUM(IM $IMPRTDMND(IM,DR,U3), XF(IM,DR,U3))
                    -SUM(SR $DD(DR,SR), .96*X(SR,DR,U3))
                    +(12/100)*Y(DR,U3)+AHY(DR,U3)=L=0;

AHCNSMPTN(DR,U3)..  AHY(DR,U3)=E=RIC(DR,U3);

*OBJECTIVE FUNCTION FOR FIXED PRICE MODEL
WLFR1..
  SUM((DR,U3), PRICE(DR,U3)*12*Y(DR,U3))
  +SUM((DR,U3), 100*PRICE(DR,U3)*AHY(DR,U3))
  +SUM((EXX,U3)$PEX(EXX,U3), PEX(EXX,U3)*BFEXPRT(EXX,U3))

  -SUM((SR,L,K1)$SRL(SR,L), R1(SR,L)*Q1(SR,L,K1))
  -SUM((SR,L,U2)$SRLHB(SR,L,U2), R3(SR,L)*Q3(SR,L,U2))
  -SUM((SRD,U5), RD(SRD,U5)*ZD(SRD,U5))
  -SUM((SR,U6), R6(SR,U6)*Z5(SR,U6))
  -SUM((SR,K7), R7(SR,K7)*Q7(SR,K7))
  -SUM((SR,K8), R8(SR,K8)*Q8(SR,K8))
  -SUM((SRR,SR)$DST(SRR,SR), (TCC(SRR,SR,'CALF')+ADJ(SRR,SR))
               *XX(SRR,SR,'CALF'))
  -SUM((SRR,SR)$DST(SRR,SR), (TCC(SRR,SR,'CALF')+ADJCF(SRR,SR))
               *XXC(SRR,SR,'CALF'))
  -SUM((SRR,SR,U7)$DST(SRR,SR), (TS(SRR,SR,U7)+ADJSF(SRR,SR,U7))
               *XXS(SRR,SR,U7))
  -SUM((SRR,SR,L)$DSRL(SRR,SR,L), (TCC(SRR,SR,'CULL')+ADJSLC(SRR,SR,L,'CULL'))
               *XXXC(SRR,SR,L,'CULL'))
  -SUM((SRR,SR,L,U7)$DSRL(SRR,SR,L), (TS(SRR,SR,U7)+ADJSLS(SRR,SR,L,U7))
```

```
                        *XXXS(SRR,SR,L,U7))
  -SUM((SRR,SR,L,U9)$DSRL(SRR,SR,L), (TF(SRR,SR,U9)+ADJSLF(SRR,SR,L,U9))
                        *XXXF(SRR,SR,L,U9))
  -SUM((SRD,SR,L)$SRL(SR,L), (TD(SRD,SR,'CULL')+ADJSLD(SRD,SR,L,'CULL'))
                        *XXXD(SRD,SR,L,'CULL'))
  -SUM((IM,DR,U3) $IMPRTDMD(IM,DR,U3), (TFI(DR,IM,U3)+MRGI(DR,IM,U3))
                        *XF(IM,DR,U3))

  -SUM((SR,EXX,U3) $T2(SR,EXX,U3), T2(SR,EXX,U3)*X2(SR,EXX,U3))
  -SUM((SR,DR,U3), T3(DR,SR,U3)*X(SR,DR,U3))=E=NSR;


       MODEL USBEEF1 /
                        DAIRYCULLS
                        DAIRYTRANS
*                        BRDNGSTCK
                        LIVESPPLY
                        TRANCULL6
                        TRANCALF6
                        CCTOSTK
                        CCUSEDSTK
                        PLACESTCK
                        TRANSFER71
                        TRANSFER72
                        CCSTCK1
                        CCSTCK2
                        CCSTCK3
                        LVANUSEFL
                        FINISHFL
                        TRANSFER8
                        TOSLGHT1
                        TOSLGHT2
                        TOSLGHT3
                        TOSLGHT4
                        TOSLGHT5
                        TOSLGHT6
                        TOSLGHT7
                        INTERMED1
                        FABRICAT
                        PLNTAGG
                        PLCPCTY
                        ALLOCFAB
                        RSTRTL
                        STKRTL
                        INTERMED3
                        HAMBURGER
*                        FATMINM
                        FATMAXM
                        SALE
                        EXTRNSPRT
                        IMTRNSPRT
                        CNSMPTN
                        AHCNSMPTN
                        WLFR1           /;
*BOUNDS ON VARIABLES

                Y.LO('MW','HMBRGR')=      4.65*PA('MW');
                Y.LO('MW','ROAST')=       1.53*PA('MW');
                Y.LO('MW','STEAK')=       1.999*PA('MW');
                Y.UP('MW','HMBRGR')=      4.65*PA('MW');
                Y.UP('MW','ROAST')=       1.53*PA('MW');
                Y.UP('MW','STEAK')=       1.999*PA('MW');
                Y.LO('NNE','HMBRGR')=     4.204*PA('NNE');
                Y.LO('NNE','ROAST')=      1.738*PA('NNE');
                Y.LO('NNE','STEAK')=      1.988*PA('NNE');
                Y.UP('NNE','HMBRGR')=     4.204*PA('NNE');
                Y.UP('NNE','ROAST')=      1.738*PA('NNE');
                Y.UP('NNE','STEAK')=      1.988*PA('NNE');
                Y.LO('S','HMBRGR')=       3.89*PA('S');
                Y.LO('S','ROAST')=         1.513*PA('S');
                Y.LO('S','STEAK')=        2.89*PA('S');
                Y.UP('S','HMBRGR')=       3.89*PA('S');
                Y.UP('S','ROAST')=        1.513*PA('S');
                Y.UP('S','STEAK')=        2.89*PA('S');
                Y.LO('W','HMBRGR')=       4.022*PA('W');
                Y.LO('W','ROAST')=        1.266*PA('W');
                Y.LO('W','STEAK')=        2.069*PA('W');
                Y.UP('W','HMBRGR')=       4.022*PA('W');
                Y.UP('W','ROAST')=        1.266*PA('W');
                Y.UP('W','STEAK')=        2.069*PA('W');
                BFEXPRT.LO('EXX1','ROAST')=.43*9.302E+04;
                BFEXPRT.UP('EXX1','ROAST')=.43*9.302E+04;
                BFEXPRT.LO('EXX1','STEAK')=.57*9.302E+04;
                BFEXPRT.UP('EXX1','STEAK')=.57*9.302E+04;
                X.UP('MW',DR,U3)=5000000000;
                Z.UP('MW',U3)=500000000;
```

```
*OPTION NLP=MINOS5;
OPTION LIMCOL=0; OPTION LIMROW=0;
OPTION ITERLIM=10000;
OPTION RESLIM=40000;
OPTION SOLPRINT=off;


     SOLVE USBEEF1 USING LP MAXIMIZING NSR;


variables
        AXXXC(SRR,SR,U6)  BEEF CULLS SHIPPED TO SLAUGHTER( HD)
        AXXXS(SRR,SR,U7)  NON-FED SHIPPED TO SLAUGHTER (HD)
        AXXXF(SRR,SR,U9)  FINISHED ANIMALS SHIPPED (HD)
        AXXXD(SRD,SR,U6)  DAIRY CULLS SHIPPED (HD)
        AX1(SRR,SR,U0)    HEAD OF FINISHED CATTLE SHIPPED

        AQ1(SR,K1)          HEAD SLAUGHTERED
        AQ3(SR,U2)    LEVEL OF HAMBURGER PROCESS USED (CWT)

        AZ0(SR,U0)    ANIMALS SLAUGHTERD (HD)
        AZ1(SR,U2)    FAB CUTS PRODUCED (CWT).
        AZ1H(SR,U2)   PRIMAL CUTS ALLOCATED TO HAMBURGER  (CWT)
        AZ1R(SR,U2)   PRIMAL CUTS ALLOCATED TO RETAIL (CWT);


        AXXXC.l(SRR,SR,U6)= sum(l $dsrl(srr,sr,l), xxxc.l(srr,sr,l,u6));
        AXXXS.l(SRR,SR,U7)= sum(l $dsrl(srr,sr,l), xxxs.l(srr,sr,l,u7));
        AXXXF.l(SRR,SR,U9)= sum(l $dsrl(srr,sr,l), xxxf.l(srr,sr,l,u9));
        AXXXD.l(SRD,SR,U6)= sum(l $srl(sr,l), xxxd.l(srd,sr,l,u6));
        AQ1.l(SR,K1)        = sum(l $srl(sr,l), q1.l(sr,l,k1));
        AQ3.l(SR,U2)    =  sum(l $srl(sr,l), q3.l(sr,l,u2));
        AZ0.l(SR,U0)    =  sum(l $srl(sr,l), z0.l(sr,l,u0));
        AZ1.l(SR,U2)    =  sum((l,k1) $srl(sr,l), z1.l(sr,l,u2,k1));
        AZ1H.l(SR,U2)   =  sum(l $srl(sr,l), z1h.l(sr,l,u2));
        AZ1R.l(SR,U2)   =  sum(l $srl(sr,l), z1r.l(sr,l,u2));

VARIABLES
          RP(DR,U3)     PRICE OF BEEF IN DEMAND REGIONS
          PY(DR,U3)     MONTHLY HOUSEHOLD CONSUMPTION OF BEEF (LBS);

TABLE MRGTST(DR,SR,U3)  MARKETING MARGIN FOR CUTS FROM WHOLESALE TO RETAIL
                          HMBRGR   ROAST    STEAK
     NNE.(SE,MW,SW,PL)      0.59   84.16   119.96
     MW.(MW,SW,PL)          1.46   77.94    36.53
     S.(SE,MW,SW,PL,W)      8.20   91.78     0.77
     W.(MW,SW,PL,W)         9.10  104.38    85.48

PARAMETER MRG(DR,SR,U3) MARKETING MARGIN USED;
          MRG(DR,SR,U3)=MRGTST(DR,SR,U3);


EQUATIONS      WLFR2  NET SOCIAL WELFARE (PRICES ENDOGENOUS);

*OBJECTIVE FUNCTION FOR EXOGENOUS PRICE MODEL
WLFR2..
12*(REX('mw')*dintc('mw','hmbrgr')*LOG(Y('mw','hmbrgr'))
+REX('mw')*1/2*bii('hmbrgr','mw')*(log(y('mw','hmbrgr'))**2)

+REX('mw')*dintc('mw','roast')*LOG(Y('mw','roast'))
+REX('mw')*bij('hmbrgr','roast','mw')*log(y('mw','hmbrgr'))*log(y('mw','roast'))
+REX('mw')*1/2*bii('roast','mw')*(log(y('mw','roast'))**2)

+REX('mw')*dintc('mw','steak')*LOG(Y('mw','steak'))
+REX('mw')*bij('steak','hmbrgr','mw')*log(y('mw','hmbrgr'))*log(y('mw','steak'))
+REX('mw')*bij('roast','steak','mw')*log(y('mw','roast'))*log(y('mw','steak'))
+REX('mw')*1/2*bii('steak','mw')*(log(y('mw','steak'))**2)

+REX('nne')*dintc('nne','hmbrgr')*LOG(Y('nne','hmbrgr'))
+REX('nne')*1/2*bii('hmbrgr','nne')*(log(y('nne','hmbrgr'))**2)

+REX('nne')*dintc('nne','roast')*LOG(Y('nne','roast'))
+REX('nne')*bij('hmbrgr','roast','nne')*log(y('nne','hmbrgr'))*
 log(y('nne','roast'))
+REX('nne')*1/2*bii('roast','nne')*(log(y('nne','roast'))**2)

+REX('nne')*dintc('nne','steak')*LOG(Y('nne','steak'))
+REX('nne')*bij('steak','hmbrgr','nne')*log(y('nne','hmbrgr'))*
 log(y('nne','steak'))
+REX('nne')*bij('roast','steak','nne')*log(y('nne','roast'))*
 log(y('nne','steak'))
+REX('nne')*1/2*bii('steak','nne')*(log(y('nne','steak'))**2)

+REX('s')*dintc('s','hmbrgr')*LOG(Y('s','hmbrgr'))
+REX('s')*1/2*bii('hmbrgr','s')*(log(y('s','hmbrgr'))**2)
```

```
+REX('s')*dintc('s','roast')*LOG(Y('s','roast'))
+REX('s')*bij('hmbrgr','roast','s')*log(y('s','hmbrgr'))*log(y('s','roast'))
+REX('s')*1/2*bii('roast','s')*(log(y('s','roast'))**2)

+REX('s')*dintc('s','steak')*LOG(Y('s','steak'))
+REX('s')*bij('steak','hmbrgr','s')*log(y('s','hmbrgr'))*log(y('s','steak'))
+REX('s')*bij('roast','steak','s')*log(y('s','roast'))*log(y('s','steak'))
+REX('s')*1/2*bii('steak','s')*(log(y('s','steak'))**2)

+REX('w')*dintc('w','hmbrgr')*LOG(Y('w','hmbrgr'))
+REX('w')*1/2*bii('hmbrgr','w')*(log(y('w','hmbrgr'))**2)

+REX('w')*dintc('w','roast')*LOG(Y('w','roast'))
+REX('w')*bij('hmbrgr','roast','w')*log(y('w','hmbrgr'))*log(y('w','roast'))
+REX('w')*1/2*bii('roast','w')*(log(y('w','roast'))**2)

+REX('w')*dintc('w','steak')*LOG(Y('w','steak'))
+REX('w')*bij('steak','hmbrgr','w')*log(y('w','hmbrgr'))*log(y('w','steak'))
+REX('w')*bij('roast','steak','w')*log(y('w','roast'))*log(y('w','steak'))
+REX('w')*1/2*bii('steak','w')*(log(y('w','steak'))**2))
+(SUM((EXX,U3)$PEX(EXX,U3), PEX(EXX,U3)*BFEXPRT(EXX,U3)))
+SUM((DR,U3), 100*PRICE(DR,U3)*AHY(DR,U3))

  -SUM((SRD,U5), RD(SRD,U5)*ZD(SRD,U5))
  -SUM((SR,U6), R6(SR,U6)*Z6(SR,U6))
  -SUM((SR,K7), R7(SR,K7)*Q7(SR,K7))
  -SUM((SR,K8), R8(SR,K8)*Q8(SR,K8))
  -SUM((SR,L),  R1(SR,L)*Q1A(SR,L))
  -SUM((SR,L,U2,K1), R3(SR,L)*Q3(SR,L,U2))

  -SUM((SRR,SR)$DST(SRR,SR), (TCC(SRR,SR,'CALF')+ADJ(SRR,SR))
                *XX(SRR,SR,'CALF'))
  -SUM((SRR,SR)$D8T(SRR,SR), (TCC(SRR,SR,'CALF')+ADJCF(SRR,SR))
                *XXC(SRR,SR,'CALF'))
  -SUM((SRR,SR,U7)$DST(SRR,SR), (TS(SRR,SR,U7)+ADJSF(SRR,SR,U7))
                *XXS(SRR,SR,U7))
  -SUM((SRR,SR,L)$DSRL(SRR,SR,L), (TCC(SRR,SR,'CULL')+ADJSLC(SRR,SR,L,'CULL'))
                *XXXC(SRR,SR,L,'CULL'))
  -SUM((SRR,SR,L,U7)$DSRL(SRR,SR,L), (TS(SRR,SR,U7)+ADJSLS(SRR,SR,L,U7))
                        *XXXS(SRR,SR,L,U7))
  -SUM((SRR,SR,L,U9)$DSRL(SRR,SR,L), (TF(SRR,SR,U9)+ADJSLF(SRR,SR,L,U9))
                        *XXXF(SRR,SR,L,U9))
  -SUM((SRD,SR,L)$SRL(SR,L), (TD(SRD,SR,'CULL')+ADJSLD(SRD,SR,L,'CULL'))
                        *XXXD(SRD,SR,L,'CULL'))

  -SUM((IM,DR,U3) $IMPRTDMND(IM,DR,U3), (TFI(DR,IM,U3)+MRGI(DR,IM,U3))
                        *XF(IM,DR,U3))
  -SUM((SR,EXX,U3) $T2(SR,EXX,U3), T2(SR,EXX,U3)*X2(SR,EXX,U3))
  -SUM((SR,DR,U3), (T3(DR,SR,U3)+MRG(DR,SR,U3))*X(SR,DR,U3))=E=NSB;


*BOUNDS ON VARIABLES
                Y.LO('MW','hmbrgr')=      2.8*pa('mw');
                Y.LO('MW','roast')=       1.2*pa('mw');
                Y.LO('MW','steak')=       1.475*pa('mw');
                Y.UP('MW','hmbrgr')=      7.7*pa('mw');
                Y.UP('MW','roast')=       2.75*pa('mw');
                Y.UP('MW','steak')=       3.5*pa('mw');
                Y.LO('NNE','HMBRGR')=     2.1*pa('nne');
                Y.LO('NNE','ROAST')=      1.0*pa('nne');
                Y.LO('NNE','STEAK')=      .8*pa('nne');
                Y.UP('NNE','HMBRGR')=     7.2*pa('nne');
                Y.UP('NNE','ROAST')=      3.3*pa('nne');
                Y.UP('NNE','STEAK')=      4.0*pa('nne');
                Y.LO('S','HMBRGR')=       2.4*pa('s');
                Y.LO('S','ROAST')=        .4*pa('s');
                Y.LO('S','STEAK')=        1.4*pa('s');
                Y.UP('S','HMBRGR')=       8.1*pa('s');
                Y.UP('S','ROAST')=        4.0*pa('s');
                Y.UP('S','STEAK')=        7.0*pa('s');
                Y.LO('W','HMBRGR')=       2.3*pa('w');
                Y.LO('W','ROAST')=        0.4*pa('w');
                Y.LO('W','STEAK')=        1.3*pa('w');
                Y.UP('W','HMBRGR')=       7.0*pa('w');
                Y.UP('W','ROAST')=        2.75*pa('w');
                Y.UP('W','STEAK')=        4.0*pa('w');
                AHY.UP(DR,U3)=RIC(DR,U3);
                AHY.LO(DR,U3)=RIC(DR,U3);
                BFEXPRT.LO('EXX1','ROAST')=.43*9.302E+04;
                BFEXPRT.UP('EXX1','ROAST')=.43*9.302E+04;
                BFEXPRT.LO('EXX1','STEAK')=.57*9.302E+04;
                BFEXPRT.UP('EXX1','STEAK')=.57*9.302E+04;
                X.UP('MW',DR,U3)=5000000000;
                Z.UP('MW',U3)=500000000;
                Q1A.UP(SR,L)=100000000;
```

```
                Z1.UP(SR,L,U2,K1)=1000000000;
                Z1H.UP(SR,L,U2)=1000000000;
                Z1R.UP(SR,L,U2)=1000000000;
                Q3.UP(SR,L,U2)=1000000000;
                X.UP(SR,DR,U3)=10000000000;
$ontext
option livespply:3:1:1; display livespply.m;
option placestck:3:1:1; display placestck.m;
option lvanusefl:3:1:1; display lvanusefl.m;
option finishfl:3:1:1; display finishfl.m;
option transfer8:3:1:1; display transfer8.m;
*option toslght1:3:1:1; display toslght1.m;
*option toslght2:3:1:1; display toslght2.m;
*option toslght3:3:1:1; display toslght3.m;
*option toslght4:3:1:1; display toslght4.m;
*option toslght5:3:1:1; display toslght5.m;
*option toslght6:3:1:1; display toslght6.m;
*option toslght7:3:1:1; display toslght7.m;
option intermed1:3:2:1; display intermed1.m;
*option fabricat:3:2:2; display fabricat.m;
$offtext

RP.L(DR,'HMBRGR')=(REX(DR)/Y.L(DR,'HMBRGR'))*(DINTC(DR,'HMBRGR')
                  +BII('HMBRGR',DR)*LOG(Y.L(DR,'HMBRGR'))
                  +BIJ('HMBRGR','ROAST',DR)*LOG(Y.L(DR,'ROAST'))
                  +BIJ('STEAK','HMBRGR',DR)*LOG(Y.L(DR,'STEAK')));

RP.L(DR,'ROAST')=(REX(DR)/Y.L(DR,'ROAST'))*(DINTC(DR,'ROAST')
                  +BIJ('HMBRGR','ROAST',DR)*LOG(Y.L(DR,'HMBRGR'))
                  +BII('ROAST',DR)*LOG(Y.L(DR,'ROAST'))
                  +BIJ('ROAST','STEAK',DR)*LOG(Y.L(DR,'STEAK')));

RP.L(DR,'STEAK')=(REX(DR)/Y.L(DR,'STEAK'))*(DINTC(DR,'STEAK')
                  +BIJ('STEAK','HMBRGR',DR)*LOG(Y.L(DR,'HMBRGR'))
                  +BIJ('ROAST','STEAK',DR)*LOG(Y.L(DR,'ROAST'))
                  +BII('STEAK',DR)*LOG(Y.L(DR,'STEAK')));
          DISPLAY RP.L;

          PY.L(dr,u3)=Y.L(dr,u3)/PA(dr);
          display PY.L;

       MODEL USBEEF2 /
                     DAIRYCULLS
                     DAIRYTRANS
*                     BRDNGSTCK
                     LIVESPPLY
                     TRANCULL6
                     TRANCALF6
                     CCTOSTK
                     CCUSEDSTK
                     PLACESTCK
                     TRANSFER71
                     TRANSFER72
                     CCSTCK1
                     CCSTCK2
                     CCSTCK3
                     LVANUSEFL
                     FINISHFL
                     TRANSFER8
                     TOSLGHT1
                     TOSLGHT2
                     TOSLGHT3
                     TOSLGHT4
                     TOSLGHT5
                     TOSLGHT6
                     TOSLGHT7
                     INTERMED1
                     FABRICAT
                     PLNTAGG
                     PLCPCTY
                     ALLOCFAB
                     RSTRTL
                     STKRTL
                     INTERMED3
                     HAMBURGER
*                     FATMINM
                     FATMAXM
                     SALE
                     EXTRNSPRT
                     IMTRNSPRT
                     CNSMPTN
                     AHCNSMPTN
                     WLFR2           /;

        OPTION NLP=MINOS5;
        OPTION LIMCOL=0; OPTION LIMROW=0;
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```
          OPTION BRATIO=1;
          OPTION ITERLIM=10000;
          OPTION RESLIM=400000;
          OPTION SOLPRINT=on;


          SOLVE USBEEF2 USING NLP MAXIMIZING NSB;

AXXXC.l(SRR,SR,U6)= sum(l $dsrl(srr,sr,l), xxxc.l(srr,sr,l,u6));
AXXXS.l(SRR,SR,U7)= sum(l $dsrl(srr,sr,l), xxxs.l(srr,sr,l,u7));
AXXXF.l(SRR,SR,U9)= sum(l $dsrl(srr,sr,l), xxxf.l(srr,sr,l,u9));
AXXXD.l(SRD,SR,U6)= sum(l $srl(sr,l), xxxd.l(srd,sr,l,u6));
AQ1.l(SR,K1)      = sum(l $srl(sr,l), q1.l(sr,l,k1));
AQ3.l(SR,U2)    =  sum(l $srl(sr,l), q3.l(sr,l,u2));
AZ0.l(SR,U0)    =  sum(l $srl(sr,l), z0.l(sr,l,u0));
AZ1.l(SR,U2)    =  sum((l,k1) $srl(sr,l), z1.l(sr,l,u2,k1));
AZ1H.l(SR,U2)   =  sum(l $srl(sr,l), z1h.l(sr,l,u2));
AZ1R.l(SR,U2)   =  sum(l $srl(sr,l), z1r.l(sr,l,u2));

*$ontext
option livespply:3:1:1; display livespply.m;
option placestck:3:1:1; display placestck.m;
option lvanusefl:3:1:1; display lvanusefl.m;
option finishfl:3:1:1; display finishfl.m;
option transfer8:3:1:1; display transfer8.m;
option toslght1:3:1:1; display toslght1.m;
option toslght2:3:1:1; display toslght2.m;
option toslght3:3:1:1; display toslght3.m;
option toslght4:3:1:1; display toslght4.m;
option toslght5:3:1:1; display toslght5.m;
option toslght6:3:1:1; display toslght6.m;
option toslght7:3:1:1; display toslght7.m;
option intermed1:3:2:1; display intermed1.m;
option fabricat:3:2:2; display fabricat.m;
display         XX.L;
display         XXC.L;
display         XXS.L;
display         AXXXC.L;
display         AXXXS.L;
display         AXXXF.L;
display         AXXXD.L;
display         XF.L;
display         AQ1.l;
display         AQ3.l;
display         ZD.L;
*display         Z5.L ;
display         Z6.L;
display         Z77.L;
display         Z7.L;
display         Z8FL.L;
display         Q8.L;
display         Z8.L;
display         AZ0.L;
display         AZ1.L;
display         AZ1H.L;
display         AZ1R.L;
*$offtext

option  X:3:2:1; display x.l;
option sale:3:1:1; display sale.m;
option cnsmptn:3:1:1; display cnsmptn.m;

*$ontext
RP.L(DR,'HMBRGR')=(REX(DR)/Y.L(DR,'HMBRGR'))*(DINTC(DR,'HMBRGR')
                  +BII('HMBRGR',DR)*LOG(Y.L(DR,'HMBRGR'))
                  +BIJ('HMBRGR','ROAST',DR)*LOG(Y.L(DR,'ROAST'))
                  +BIJ('STEAK','HMBRGR',DR)*LOG(Y.L(DR,'STEAK')));

RP.L(DR,'ROAST')=(REX(DR)/Y.L(DR,'ROAST'))*(DINTC(DR,'ROAST')
                  +BIJ('HMBRGR','ROAST',DR)*LOG(Y.L(DR,'HMBRGR'))
                  +BII('ROAST',DR)*LOG(Y.L(DR,'ROAST'))
                  +BIJ('ROAST','STEAK',DR)*LOG(Y.L(DR,'STEAK')));

RP.L(DR,'STEAK')=(REX(DR)/Y.L(DR,'STEAK'))*(DINTC(DR,'STEAK')
                  +BIJ('STEAK','HMBRGR',DR)*LOG(Y.L(DR,'HMBRGR'))
                  +BIJ('ROAST','STEAK',DR)*LOG(Y.L(DR,'ROAST'))
                  +BII('STEAK',DR)*LOG(Y.L(DR,'STEAK')));
display RP.L;
PY.L(dr,u3)=Y.L(dr,u3)/PA(dr);
display PY.L;
*$offtext
```

APPENDIX D
THE EMPIRICAL COMPENSATED DEMAND SYSTEM

This section demonstrates how to obtain the empirical compensated demand system from the estimated demand system. The compensated demand system as derived from the distance function is

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln q_j + U\beta_i\beta_o\Pi q_i^{\beta_i} \qquad (D.1)$$

where

$$U = -(a_o + \sum_i \alpha_i^* \ln q_i + 1/2\Sigma_i\Sigma_j \gamma_{ij} \ln q_i \ln q_j)/\beta_o\Pi q_i^{\beta_i} \qquad (D.2)$$

and the following parameter restrictions hold: $\Sigma\alpha_i = 1$, $\Sigma_i \gamma_{ij} = \Sigma_j \gamma_{ij} = \Sigma\beta_i = 0$, and $\gamma_{ij} = \gamma_{ji}$.

In order to obtain the empirical compensated demand system, it is necessary to set a value for $U\beta_o$ in equation D.1 and hold it constant. This can be accomplished by substituting

$$a(q) = a_o + \sum_i \alpha_i^* \ln q_i + 1/2\Sigma\Sigma_{ij} \gamma_{ij} \ln q_i \ln q_j \qquad (D.3)$$

in equation D.2 and solving for $U\beta_o$. The resulting demand equation is

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln q_j + \phi\beta_i \Pi q_i^{\beta_i} \qquad (D.4)$$

where

$$\phi = - \bar{a}(q)/\Pi \bar{q}_i^{\beta_i} \qquad (D.5)$$

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BIOGRAPHICAL SKETCH

Mark A. Peters was born on July 31, 1956, in New Kensington, Pennsylvania, where he spent a typical childhood. After high school graduation from Willowbrook Community High School, he studied political science at Lew and Clark College in Portland, Oregon, where he received a B.A. in 1979. From 1979-1982, he served with the U.S. Peace Corps in Jamaica on an integrated rural development project. In August 1983, he entered the graduate program in food and resource economics at the University of Florida where he received an M.S. in 1987, and where he will receive a Ph.D. in December 1990.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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